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**Ludlow
and Pridoli**
(Upper Silurian)

**Graptolites from the
Arctic Islands, Canada**

ALFRED LENZ

ANNA KOZŁOWSKA-DAWIDZIUK



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Abstract

A moderately diverse fauna of Ludlow and Pridoli monograptids and retiolitids is described from Arctic Canada. The genus and species diversity of the lower and middle Ludlow monograptids is moderate, whereas that of the upper Ludlow is distinctly impoverished in comparison with coeval faunas of the Czech Republic, and of northeastern Poland and Ukraine (both part of the East European Platform), and Kazakhstan. Of particular note is the rarity or absence of members of the lobograptid, neolobograptid, cucullograptid, and neocucullograptid groups. Thus, there is a disparity in both species and morphologic diversity. The Pridoli, by contrast, shows a moderate diversity in comparison with other Pridoli sequences, both at the species and morphological levels, although some species of *Monograptus* are absent. Retiolitid diversity is relatively high in comparison with Polish sequences (the only other comprehensive sequence of isolated Ludlow species), but there is a considerable difference in species content. From the biogeographic viewpoint, the presence of a number of apparently endemic species of both monograptid and retiolitid species, among them species of *Pseudomonoclimacis*, *Monograptus*, including *Monograptus ceratus*, and *Neogothograptus*, suggests that the region was, at times, partially isolated from other parts of the world. It is suggested that a combination of effects, including sea-level

changes, physical barriers, and variable oceanic currents combined at crucial times, to partially isolate the Arctic regions, especially during the late Ludlow.

The fauna comprises 34 species of monograptids of which 10 are from the Pridoli, and 12 species of retiolitids from the Ludlow. Three new species and subspecies of monograptids, *Monograptus microdon curvatus*, *Pseudomonoclimacis dalejensis rectus*, and *Pseudomonoclimacis brevicucullus*, and four new species and subspecies of retiolitids, *Neogothograptus purus labiatus*, *Neogothograptus alatiformis*, *Neogothograptus melchini* and *Neogothograptus thorsteinssoni*, are described. In addition, seven species of dendroids and one species of a tuboid are identified using open nomenclature. The Ludlow sequence (from oldest to youngest) is divided into the *Lobograptus progenitor*, *Lobograptus scanicus*, *Saetograptus linearis* – *Monograptus ceratus*, *Bohemograptus bohemicus tenuis* – *Bohemograptus praecornutus*, and *Formosograptus formosus* biozones, and that of the Pridoli comprises the *Neocolonograptus parultimus*, *Neocolonograptus ultimus*, *Neocolonograptus branikensis*, *Monograptus bouceki*, *Neocolonograptus? transgrediens*, and *Monograptus birchensis* biozones. The *Monograptus birchensis* Biozone appears to straddle the Silurian–Devonian boundary.

Résumé

Est décrite une faune de diversité moyenne composée de monograptides et de rétiolitides du Ludlow et du Pridoli de l'Arctique canadien. Il y a une diversité moyenne des genres et espèces de monograptides du Ludlow hâtif et moyen, tandis que la diversité du Ludlow tardif est nettement appauvrie comparativement à la faune contemporaine de la République tchèque, du nord-est de la Pologne et de l'Ukraine (qui font toutes deux partie de la plate-forme de l'Europe orientale) ainsi que du Kazakhstan. Il convient particulièrement de souligner la rareté ou l'absence de membres des groupes des lobograptides, néolobograptides, cucullograptides et néocucullograptides. Ainsi, il y a disparité à la fois de la diversité spécifique et morphologique. L'ère pridolienne, par contraste, comporte une diversité moyenne en comparaison avec les autres séquences du Pridoli à la fois aux niveaux spécifique et morphologique, bien que certaines espèces de *Monograptus* soient absentes. La diversité des rétiolitides est relativement grande comparativement aux séquences de la Pologne (seule autre séquence importante d'espèces isolées du Ludlow), mais il y a une différence considérable dans le contenu des espèces. D'un point de vue biogéographique, la présence d'un nombre d'espèces apparemment endémiques à la fois de monograptides et de rétiolitides, entre autres les espèces *Pseudomonoclimacis*, *Monograptus*, y compris *Monograptus ceratus* et *Neogothograptus*, ce qui laisse entendre que la région a à l'occasion été partiellement isolée des autres régions du monde. Il est

suggéré qu'un agencement d'effets, y compris les changements au niveau de la mer, les obstacles physiques et les courants océaniques variables à des époques cruciales, ont partiellement isolé les régions arctiques, surtout au Ludlow tardif.

La faune comprend 34 espèces de monograptides, parmi lesquelles 10 du Pridoli, de même que 12 espèces de rétiolitides du Ludlow. Trois nouvelles espèces et sous-espèces de monograptides : *Monograptus microdon curvatus*, *Pseudomonoclimacis dalejensis rectus* et *Pseudomonoclimacis brevicucullus*, ainsi que quatre nouvelles espèces et sous-espèces de rétiolitides : *Neogothograptus purus labiatus*, *Neogothograptus alatiformis*, *Neogothograptus melchini* et *Neogothograptus thorsteinssoni* sont décrites. De plus, sept espèces de dendroïdes et une espèce de tuboides sont identifiées au moyen d'une nomenclature libre. La séquence du Ludlow (du plus tardif au plus hâtif) est divisée en biozones à *Lobograptus progenitor*, *Lobograptus scanicus*, *Saetograptus linearis* – *Monograptus ceratus*, *Bohemograptus bohemicus tenuis* – *Bohemograptus praecornutus*, et *Formosograptus formosus*, tandis que la séquence du Pridoli comprend les biozones à *Neocolonograptus parultimus*, *Neocolonograptus ultimus*, *Neocolonograptus branikensis*, *Monograptus bouceki*, *Neocolonograptus? transgrediens*, et *Monograptus birchensis*. La biozone à *Monograptus birchensis* semble recouper l'intervalle silurien-dévonien.

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Introduction

Studies of Ludlow and Pridoli graptolites of the Canadian Arctic Islands are few and relatively recent. The first indication of the richness of Arctic graptolite faunas stems from the pioneering work of Thorsteinsson (1958) who, while mapping the geology of Cornwallis Island, described and named the Cape Phillips Formation, the main graptolite-bearing unit in the Arctic Islands. He recognized that, at the type section, the Cape Phillips Formation ranged from Upper Llandovery to Upper Ludlow (part of the latter being subsequently recognized as Pridoli) and discovered, for the first time, that the numerous calcareous nodules ranging through the lower part of the type section, as well as in other sections in the northern part of the island, preserved rich faunas of beautifully preserved, uncompressed graptolites. These are among the finest in the world, and equal in quality to those from the Baltic region, as described for example, by Eisenack (1951), Urbanek (1958, 1966, 1997a), and Kozłowska-Dawidziuk (1995).

Subsequent mapping by the Geological Survey of Canada throughout a large part of the Arctic Islands, and beginning in the following decade, produced a number of reports, many of which listed and utilized graptolites for biostratigraphic purposes. For example, the large regional mapping publication edited by Fortier (1963), and many individual reports such as those of Kerr (1974), Trettin (1979), and Thorsteinsson (1980), made extensive use of graptolites for age dating and correlation. None of these publications, however, described or illustrated graptolite species.

Published broad-basis taxonomic studies of Arctic graptolites began with Lenz and Melchin (1987) who examined collections of isolated, uncompressed retiolitids, some of

which were from the Lower Ludlow. Work continued with the preliminary biostratigraphic study of Ludlow and Pridoli graptolites, mostly from flattened material, made by Lenz (1990). That study set up a biostratigraphic scheme only slightly less detailed than the one used in this study, and illustrated many of the more common and biostratigraphically important monograptid species. This was followed by a small study of some isolated Wenlock and Ludlow monograptid species (Lenz 1992). Finally, much larger and more comprehensive taxonomic and biostratigraphic studies of isolated retiolitids, again including some from the Ludlow, followed from Lenz (1993, 1994). Most recently, and although not directly focussed on, nor concerned solely or specifically with Ludlow–Pridoli graptolites of the Arctic, many data from the studies of Arctic Ludlow monograptids and retiolitids were incorporated into several papers by Lenz and Kozłowska-Dawidziuk (2001a, 2002) and Kozłowska-Dawidziuk (2002).

The present study updates the Ludlow–Pridoli graptolite biostratigraphic scheme, compares the Arctic species diversity and geographic distribution with coeval sequences elsewhere in the world, describes and illustrates almost all known species of flattened and isolated Ludlow and Pridoli monograptids and retiolitids from Arctic Canada, and places all the described species within the overall biostratigraphic sequence. The work relies heavily on the study of the isolated, uncompressed monograptids and retiolitids that have been released from limestones by slow dissolution in very dilute hydrochloric. Particularly important is the presence of isolated retiolitids, since their complex morphology can seldom be fully understood solely through the study of flattened specimens.

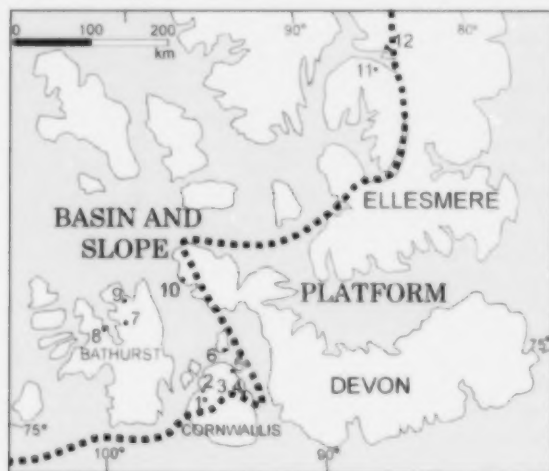
Stratigraphy

The main graptolite-bearing unit of the central Arctic Islands, the Cape Phillips Formation, is a very widespread deep-water, shelf-margin to basin stratigraphic unit that lies to the west and northwest of a widely distributed shallow water carbonate platform to shelf-margin sequence (Fig. 1). The boundary between the two major lithofacies is relatively abrupt. The Cape Phillips Formation was first described from northeastern Cornwallis Island by Thorsteinsson (1958) who recognized three informal members A, B, and C. Only Member C that regionally ranges in age from Late Llandovery to latest Silurian or Early Devonian, is relevant to this study. Lithologically, Member C of the Cape Phillips Formation consists of varying proportions of dark shales, shaly limestones/calcareous shales, and dark carbonates. Close to the shelf margin, for example at the Cape Phillips type locality, Abbott River, Snowblind Creek, and Baillie Hamilton Island, carbonates make up at least 50% of the section, at least in the lower one-half of the sections, and calcareous concretions and nodular limestones are fairly common. It is in the concretions and nodular limestones that the beautifully preserved, uncompressed graptolites are com-

monly preserved. In the more basin-ward sections, Twilight Creek, Humphries Hill, Strathcona Fiord, and Grant Point, shales predominate throughout, and graptolites are preserved almost exclusively in flattened form on the shale surfaces. Graptolite-bearing nodules are rare in these sequences, with the exception of part of the shale section at Cape Sir John Franklin, and a few in the lowest Ludlow of Grant Point. Generally speaking, many of the shales, shaley limestones and calcareous shales are beautifully and evenly laminated, never or rarely weakly bioturbated, and the few benthic organisms such as brachiopods, corals, trilobites, sponges and bivalves that are present are clearly transported, all pointing to quiet, below wave-base, anoxic conditions. Carbonate debris flows, some with abundant benthic faunas, particularly brachiopods and trilobites, are fairly common in the Llandovery and Wenlock, less common in the Ludlow, and virtually absent in the Pridoli.

A secondary graptolite-bearing unit, the Bathurst Island Formation (Fig. 2), was originally described from Twilight Creek, Bathurst Island, by McLaren (in Fortier et al. 1963). The unit conformably overlies the Cape Phillips Formation

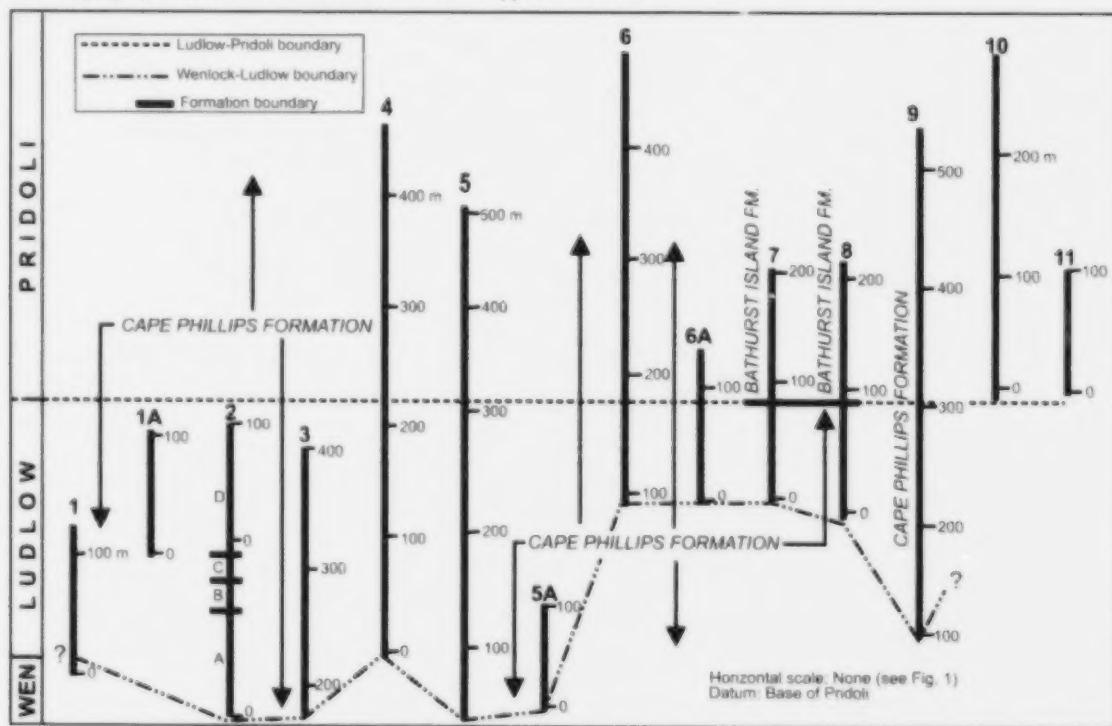
Fig. 1. Index map of the central Arctic Islands showing section localities. Sections are as follows: 1. Abbott River; 2. Rookery Creek; 3, 4. Snowblind Creek; 5. Cape Phillips; 6. Baillie Hamilton Island; 7. Twilight Creek; 8. Grant Point; 9. Humphries Hill; 10. Cape Sir John Franklin; 11. Strathcona Fiord; 12. Irene Bay. Dashed line delineates the approximate boundary between the shallow water platform carbonate facies (to the east and south-east) and the slope and basin.



and consists predominantly of shales, siltstones, and fine sandstones. At the type section, its base is of Early Devonian age (Kerr 1974) and is, therefore, without relevance to this study. Elsewhere, for example at Grant Point and Humphries Hill, however, the lowest parts of the formation lie within the uppermost Pridoli while only the higher parts range into the Lower Devonian (see Fig. 2); the unit yields only flattened graptolites.

Ludlow and Pridoli rocks attain a considerable thickness, commonly hundreds of metres, whether in the carbonate-rich shelf margin sections, or in the more offshore, elastic-rich facies (see Fig. 2). Characteristically, they are often much thicker than the Llandovery and Wenlock parts of any sequence. At the type locality, for example, an incomplete sequence of Ludlow and Pridoli rocks is more than 500 m thick, whereas the combined (incomplete) Llandovery–Wenlock thickness is about 350 m. Even more striking is the Twilight Creek section where the complete Llandovery–Wenlock part of the sequence attains a thickness of only about 200 m, whereas the Ludlow–Pridoli rocks are more than 500 m thick. The combined thickness of Ludlow and Pridoli rocks of each section sampled for this study is shown in Fig. 2.

Fig. 2. Section correlation, thickness, and approximate Ludlow–Pridoli boundary (section numbering same as in Fig. 1). Base of Pridoli is the datum. Position of Cape Phillips and Bathurst Island formations are shown on sections. For a complete listing of the faunas and the geographic coordinates of each section, see Appendices 1 and 2.



1. 1A. Abbott River (AB2-99, AB4-99, respectively). 2. Snowblind Creek (SB90, A-D, AB97, A-D). 3. Snowblind Creek (SB90 F). 4. Cape Phillips (CP77). 5. 6A. Baillie Hamilton Island (BH2-98, BH-91). 6. 6A. Twilight Creek (TC88; TWW & TWN 94). 7. Grant Point (GP96). 8. Humphries Hill (HH94). 9. Cape Sir John Franklin (SJF89). 10. Strathcona Fiord (SF93). 11. Irene Bay (IB).

Non-graptolite faunas

The abundance of non-graptolite faunas is very variable, but benthic organisms are much more common in the carbonate-rich sections, often in debris flows. Radiolarians, like the graptolites, are common to abundant in most dark, organic-rich carbonates at most localities (see, for example, Goodbody 1986, Noble 2000) although more common in Llandovery and Wenlock rocks than in the Ludlow, in part because of the decrease in carbonates, particularly dark, nodular carbonates, higher in the sequences. The radiolarian yield in Pridoli rocks is, at present, poorly known. Other pelagic organisms include palynomorphs such as chitinozoans and plant microfossils (which can sometimes be common), and phyllocarids, but none of these groups has, at present, been systematically studied.

Benthic faunas, most of which have been brought into the basin environment as parts of debris flows, are sporadic. Brachiopods, many of which are silicified, can be particularly abundant and diverse, the faunas being dominated by representatives of the moderate depth pentamerid to deep-

water *Dicoelosia* communities. Although some of the brachiopods from the Llandovery and Wenlock have been documented (e.g., Zhang 1989), those from the Ludlow (brachiopods are rare in the basinal Pridoli part of the sequences) have not been described. Trilobites, many beautifully silicified, occur sporadically but fairly frequently through most of the Silurian, and can be abundant and highly diverse. Their biostratigraphic sequences, which are integrated with the graptolite biozonation, are well documented, and are among the best continuous Llandovery to Ludlow sequences in the world (see, for example, Adrain and Ramsköld 1997, Adrain and Edgecombe 1997). Sponges, both siliceous and calcareous, while not common, are widely distributed in the carbonates, including those in the Ludlow, and are often beautifully preserved (see, for example, de Freitas 1991). Other benthic organisms such as corals and bivalves are relatively rare, but are sometimes associated with brachiopods in debris flow deposits.

Biostratigraphy

Biostratigraphic studies of Ludlow-Pridoli graptolites of the Canadian Arctic are few. Thorsteinsson's (1958) preliminary studies recognized a small number of biozones, including several informal biozones, in the Ludlow and Pridoli. A more detailed and more formal biozonation of Ludlow-Pridoli graptolite sequences was proposed by Lenz (1990) who recognized the *progenitor*, *fritschii linearis*, and *bohemicus tenuis* biozones in the Ludlow, and the *formosus*, *ultimus*, *houceki*, *transgrediens*, and *birchensis* biozones in the Pridoli, although there was, and still is, doubt about the range and correlation of the *birchensis* Biozone. The present study, based on graptolite collections from seven stratigraphic sections, in which only the broad, generalized lithologic characteristics are shown in Figs. 3-9, incorporates both flattened and isolated, uncompressed graptolite species, and recognizes several more biozones, renames and refines two others, provides a few more data on the *birchensis* Biozone, and assigns the *formosus* Biozone to the uppermost Ludlow (following the Generalized Graptolite Zonation of Koren et al. 1995). The Ludlow is divided, from lower to higher, into the *progenitor*, *scanicus*, *linearis-ceratus*, *bohemicus tenuis* - *praecornutus*, and *formosus* biozones, while the *parultimus*, *ultimus*, *branikensis*, *houceki*, *transgrediens*, and *birchensis* biozones are recognized in the Pridoli. A composite of the species content of the biozones and of the ranges of all species of monograptids recognized in this study is shown in Fig. 10.

Lobograptus progenitor Biozone

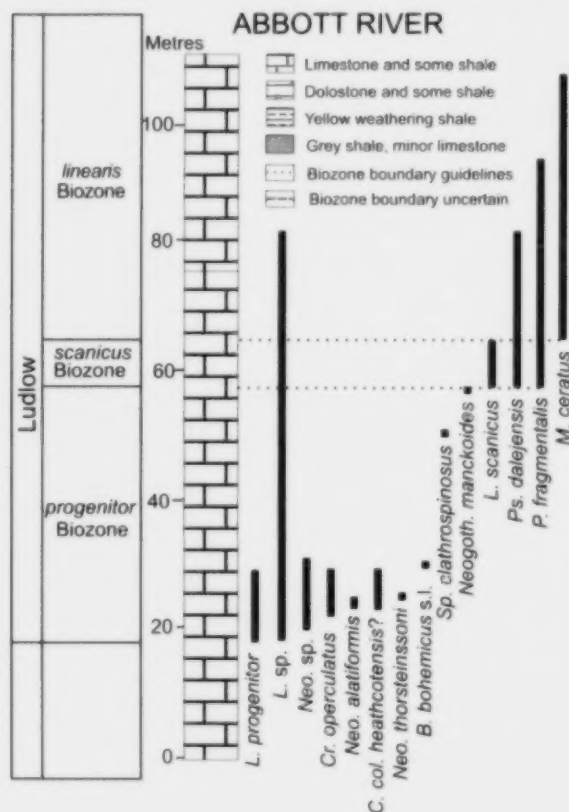
The *progenitor* Biozone is recognized by the first occurrence of the zonal species or, alternatively, *Colonograptus colonus heathcotensis* or *Bohemograptus bohemicus bohemicus*. The last, while being exceptionally widespread and

common throughout the biozone, ranges well above the upper boundary of the biozone. Less common monograptid species through the biozone include *Lobograptus* spp., *Bohemograptus garratti*, *Saetograptus varians*, and, rarely, *Crinitograptus operculatus*. *Pseudomonoclimacis dalejensis rectus* n. subsp. makes its first occurrence in this zone, but extends into the *linearis-ceratus* Biozone. The partial or, possibly, full equivalent to this biozone in Europe, for example, commonly contains *Neodiversograptus nilssoni* underlying *L. progenitor*; however, *Neodiversograptus nilssoni* has never been firmly identified in either the Arctic Islands, or in northern Yukon. Arctic material identified by Thorsteinsson (1958) as that species is almost certainly *Lobograptus progenitor*. Furthermore, as in the Arctic, only *Lobograptus progenitor* occurs in this interval in the southern Tien Shan region, Central Asia (Koren and Sujarkova 2003), and it seems reasonable to conclude that the *progenitor* Biozone of the Arctic correlates with the combined *nilssoni* and *progenitor* biozones of the British Isles, Czech Republic, and Poland. This biozone is by far the richest in species diversity both among the monograptids and the retiolitids. Among the latter, every species presently recognized in the Arctic Ludlow occurs in this biozone. Some species of *Spinograptus* and *Plectograptus* continue from Wenlock strata, whereas all known species of *Neogothograptus* and *Holoretiolites* appear for the first time. This biozone is the most commonly and widely recognized Ludlow biozone in the Arctic.

Lobograptus scanicus Biozone

This biozone is documented in the Arctic for the first time, but is recognized in only two sections, Abbott River and Cape Sir John Franklin. Its base is defined by the first occurrence of the name-species or by that of *L. parascani-*

Fig. 3. Abbott River section showing biozonation and species distribution. Lithology symbols shown in inset. *Lin.*, *Linograptus*; *Neogoth.*, *Neogothograptus*; *L.*, *Lobograptus*; *Cr.*, *Crinograptus*; *C.*, *Colonograptus*; *B.*, *Bohemograptus*; *Sp.*, *Spinograptus*; *Ps.*, *Pseudomonoclimacis*; *P.*, *Pristiograptus*; *M.*, *Monograptus*; *S.*, *Saetograptus*; *F.*, *Formosograptus*; *Ncl.*, *Neocolonograptus*.

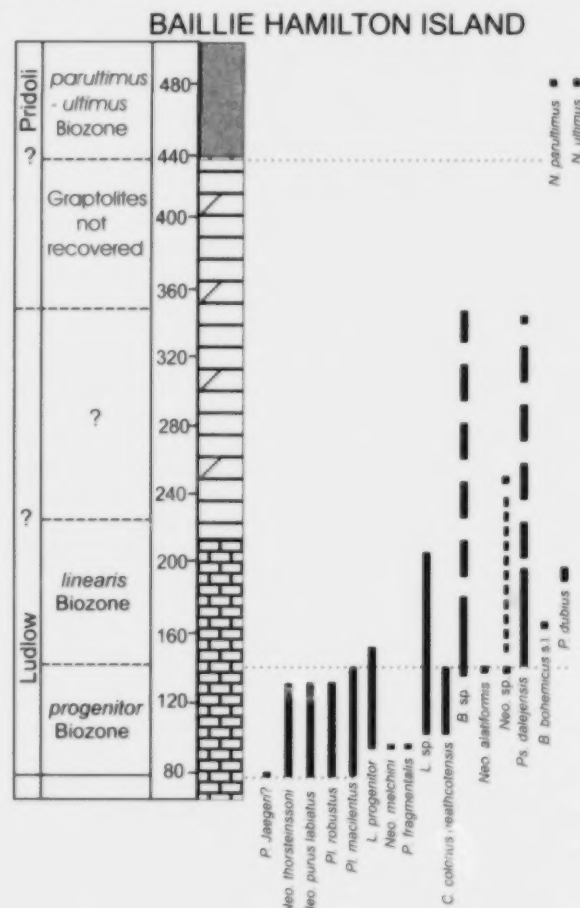


cus. Diversity is moderate. *B. h. bohemicus* is common, with rare specimens of *Pseudomonoclimacis brevicucullus* n. sp., *Ps. dalejensis dalejensis*, *Pristiograptus fragmentalis*, and *Linograptus posthumus tenuis*. Several other long-ranging, but less common, species continue from the underlying *progenitor* Biozone. Retiolitids are not common in the zone, although this is probably, in part, a reflection of the difficulty in recognizing the *scanicus* Biozone. Nevertheless, four species are recognized (see Fig. 14).

***Saetograptus linearis* – *Monograptus ceratus* Biozone**

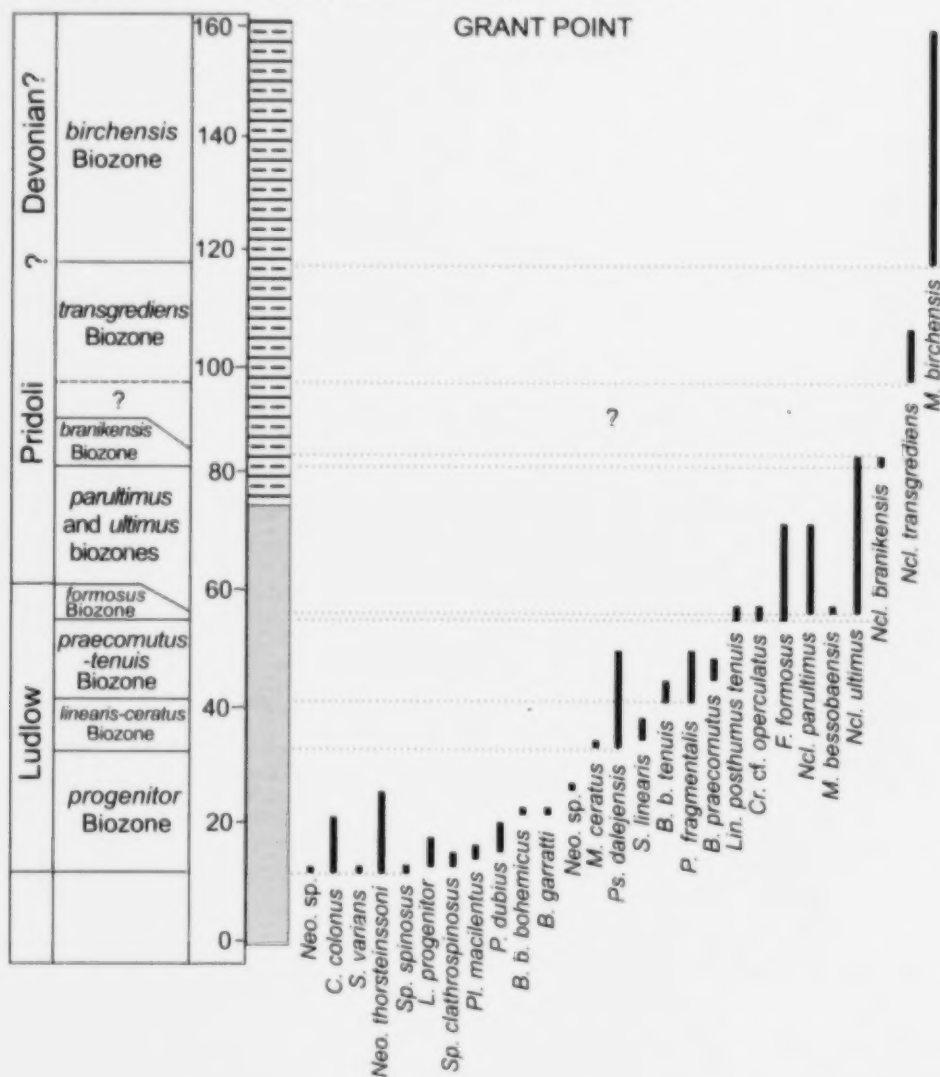
The zone is defined by the first occurrence of either of the eponymous species, although *S. linearis* is much more commonly found. Other species occurring in, but not restricted to the zone, include *Pseudomonoclimacis dalejensis dalejensis*, *Ps. dalejensis rectus* n. subsp., *Pristiograptus fragmentalis*, *B. bohemicus bohemicus*, and some other less common long-ranging species. *Ps. dalejensis dalejensis* is particularly common in this zone and, thus, is used to very tentatively define the base of the *linearis*–*ceratus* Biozone in Fig. 4.

Fig. 4. Baillie Hamilton Island section showing biozonation and species distribution.



Pseudomonoclimacis hispinosus appears to be confined to the zone, but is rare. A very rare and incompletely preserved form, similar to *Neodiversograptus beklemishevi* also occurs in the zone. *Bohemograptus bohemicus tenuis* is rarely found in the zone. The monograptid genus *Egregiograptus*, typical in this and higher biozones elsewhere (e.g., Štorch, 1995; Rickards and Wright, 1997), has not been found to date in the Arctic; however, it does occur in this biozone in northern Yukon where it was originally described as *Bohemograptus?* sp. (Lenz, 1984) and subsequently named *Egregiograptus pribyli* by Rickards and Wright (1997). Considering the very close relationship between the Ludlow faunas of the Arctic and northern Yukon, the genus could be expected in the Arctic. Retiolitids are rare, and comprise only species of *Neogothograptus* and *Spinograptus*; and reach their stratigraphically highest known occurrence in this biozone in the Arctic. In Poland, *Plectodinemagraptus* and *Holoretiolites* range into the *hemiaversus* Biozone, a biozone approximately equivalent to the *linearis*–*ceratus* Biozone of the Arctic (see Figs. 11 and 14). In Central Asia some retiolitids extend slightly higher into the *podoliensis* Biozone (Koren' and Sujarkova 2003).

Fig. 5. Grant Point section, Bathurst Island, showing biozonation and species distribution.



Bohemograptus bohemicus tenuis – *B. praecornutus* Biozone

Although *Bohemograptus bohemicus tenuis* is uncommonly found in the underlying zone, it is much more common in this higher zone, and its interval of maximum abundance may be looked upon as an abundance zone. The species, accompanied by *B. praecornutus*, characterize the zone, although the latter species is uncommon. Alternatively, the biozone, while not clearly defined, can be considered as the interval between the highest occurrences of either *Monograptus ceratus* or *Saetograptus linearis*, and the lowest occurrence of *Formosograptus formosus*. Diversity in the zone is only moderate, mostly due to the continuation of long-ranging species, chief among them being *Ps. dalejensis*, *Pristiograptus fragmentalis*, and *Linograptus posthumus tenuis*. The rare and unusual species, *Bohemograptus? helicoides*, may occur in this biozone, although

this suggestion is solely based on extrapolation from its biostratigraphic position in Yukon. Retiolitids are unknown, although it is possible that their absence may, in part, be a reflection of the generally low diversity of any kind of graptolites in this biozone (see below).

Formosograptus formosus Biozone

The zone is defined by the first occurrence of the name-species, although the species ranges well into the Pridoli, and is the only species (in addition to the *Linograptus posthumus* group) to cross the Ludlow-Pridoli boundary, apparently unchanged morphologically. *Monograptus* cf. *beatus*, is apparently restricted to the zone, and *Crimitograptus* cf. *operculatus* first occurs in the biozone, but ranges into the overlying *parultimus* Biozone. *Linograptus posthumus tenuis* is fairly common in the zone, but appears lower in the Ludlow and ranges much higher.

Fig. 6. Humphries Hill section, Bathurst Island, showing biozonation and species distribution.

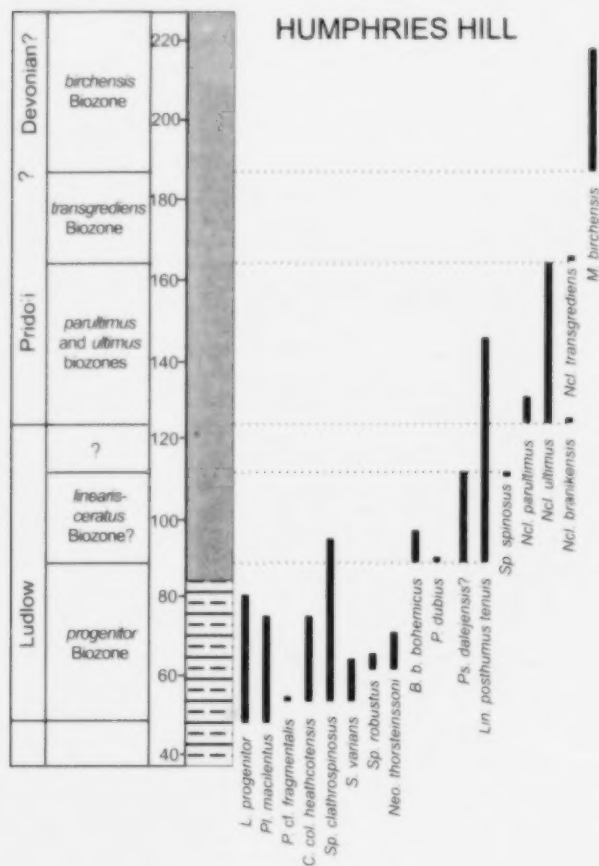
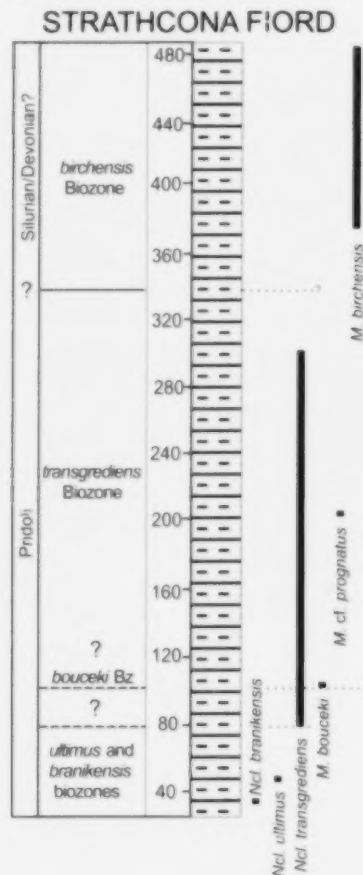


Fig. 7. Strathcona Fiord section, Ellesmere Island, showing biozonation and species distribution.



Neocolonograptus parultimus Biozone

This lowest Pridoli zone is recognized exclusively by the first occurrence of the index species. It may be accompanied by *Formosograptus formosus*, *Linograptus posthumus tenuis*, *Crinitograptus* cf. *operculatus* and *Monograptus besso-baensis*.

Neocolonograptus ultimus Biozone

This zone is typically recognized solely by the first occurrence of the name-species, although in one section (Fig. 5) *N. parultimus* and *N. ultimus* first occur together. The zone may also contain the highest occurrence of *Formosograptus formosus* as well as rare occurrences of *Monograptus besso-baensis*, and *Neocolonograptus norfordi*.

Neocolonograptus branikensis Biozone

The zone is recognized in only one section (Fig. 9) and is characterized by the occurrence of the zonal species which is confined to the lower part of the biozone. It may contain the long-ranging *Linograptus posthumus tenuis* and the highest occurrence of *Neocolonograptus ultimus*.

Monograptus bouceki Biozone

The zone is defined entirely by the occurrence of the name-species, which occurs only very rarely. The name-species, and therefore the biozone, is much better known in northern Yukon (Jackson and Lenz 1972). The earliest occurrences of *Neocolonograptus transgrediens* and the highest occurrences of *Linograptus posthumus tenuis* may also characterize the zone.

Neocolonograptus transgrediens Biozone

This biozone is somewhat nebulously defined by the first occurrence of the name-species above the occurrence of *M. bouceki*. In the absence of *M. bouceki*, the biozone is defined solely by the first occurrence of the name-species and, in that case, can be considered as a range biozone. The very rare and poorly defined species *Monograptus* cf. *prognatus* Koren' occurs in this zone. The species' range and, consequently the zone, may be thick: in the Strathcona Fiord and Twilight Creek sections, for example, the species ranges through more than 150 m, and in both cases, its upper range limit is only poorly defined.

Fig. 8. Cape Sir John Franklin section, Devon Island, showing biozonation and species distribution.

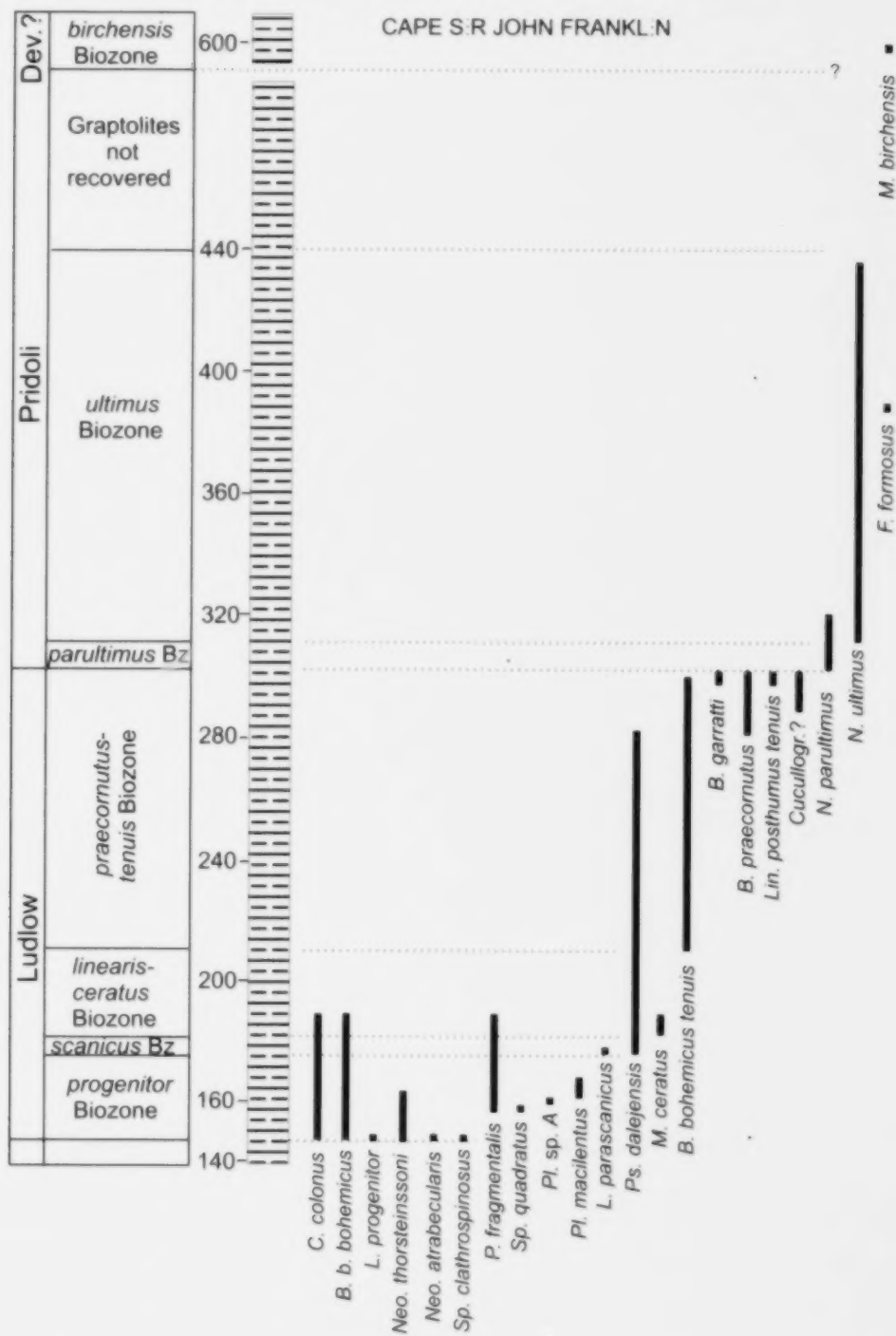
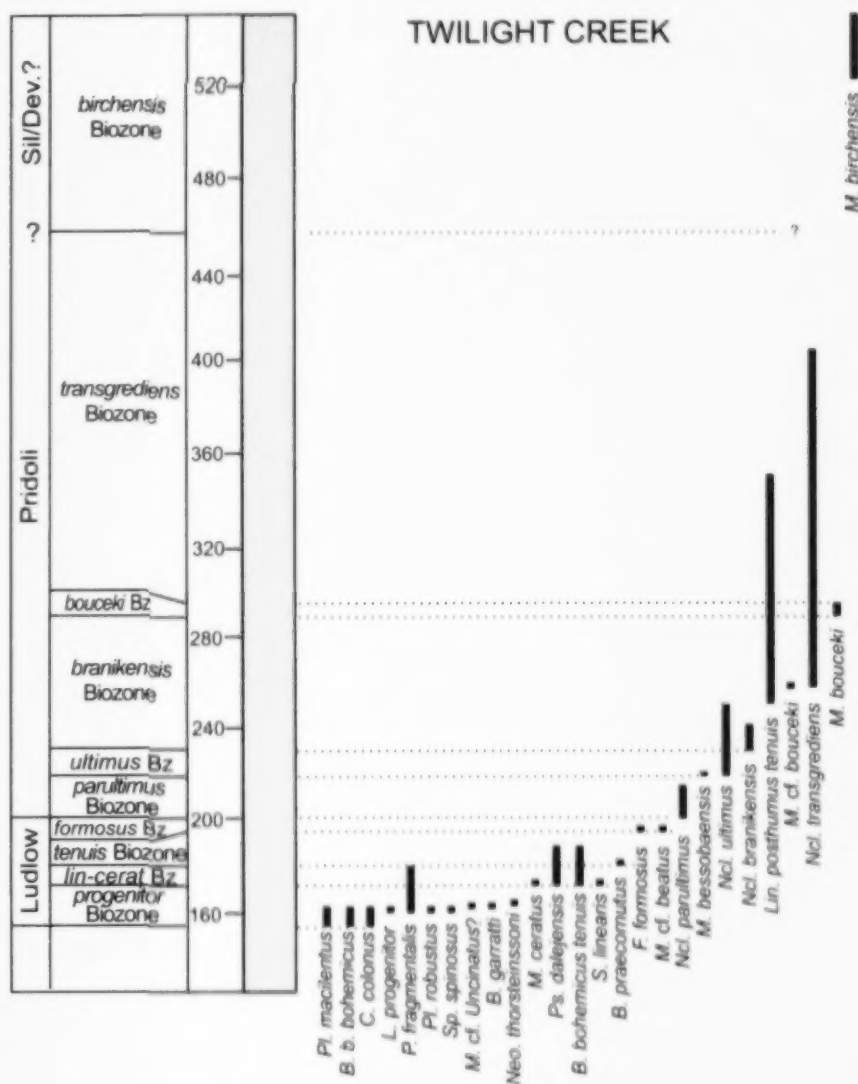


Fig. 9. Twilight Creek section, Bathurst Island, showing biozonation and species distribution.

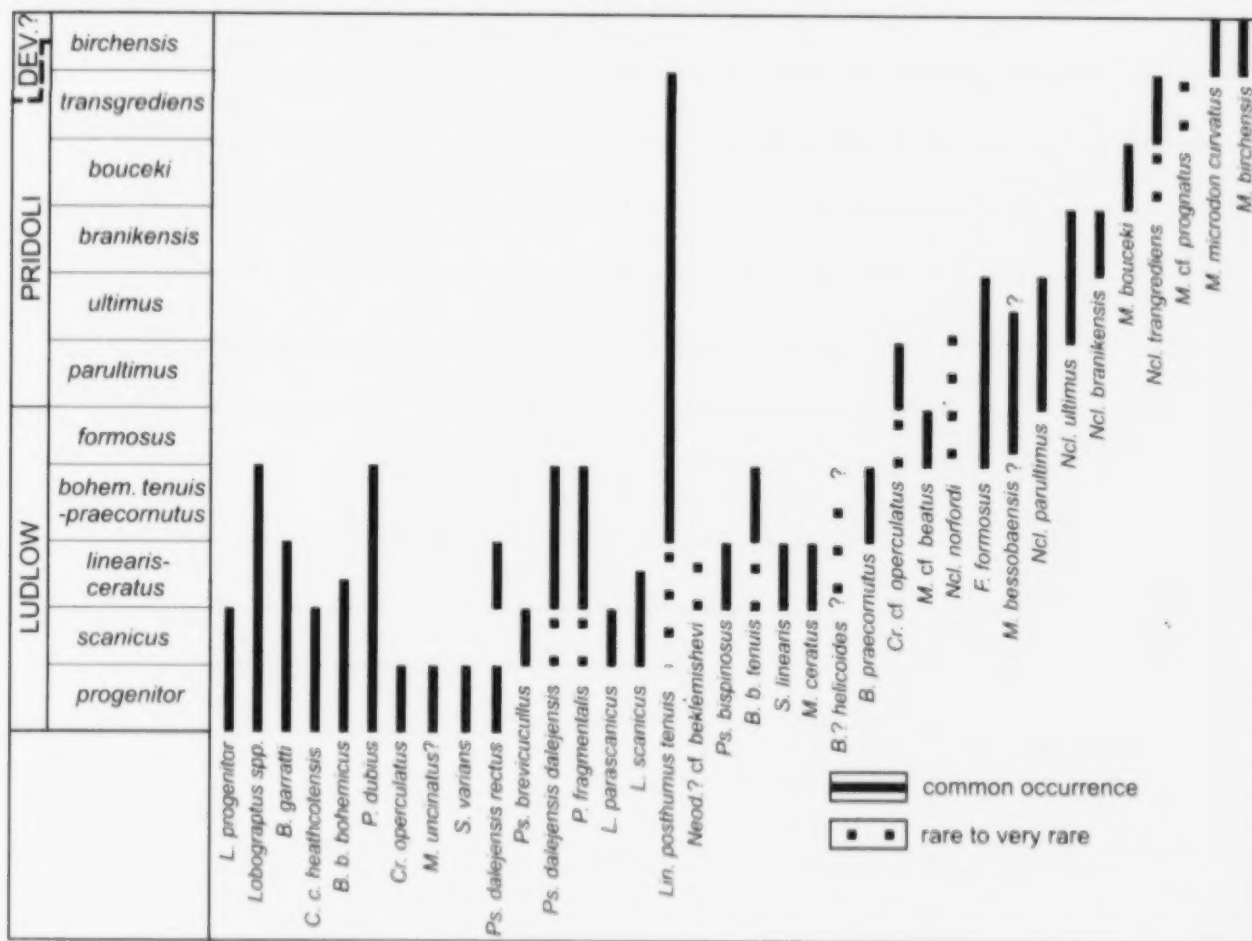


Monograptus birchensis Biozone

This zone is recognized, characterized, and defined almost solely by the occurrence of the name-species. Correlation of the biozone with either the uppermost Silurian or lowermost Devonian remains difficult, since it occurs mainly as monospecific assemblages or, in one instance, with *Monograptus microdon curvatus* n. subsp. In the Twilight Creek section,

however, a thick stratigraphic interval yielding nothing but the eponymous species is overlain by strata bearing the earliest Devonian species *Monograptus uniformis*. The first occurrence of *M. birchensis* there is probably within the uppermost Silurian, although its age in other sections is unclear. In its three Nevada sections occurrences, it has been found only in Early Devonian strata in association with *Monograptus uniformis* (Berry and Murphy 1975).

Fig. 10. Composite biostratigraphic range chart of all monograptids species recorded from the Arctic.



Biozonal correlation, species diversity, and biogeography

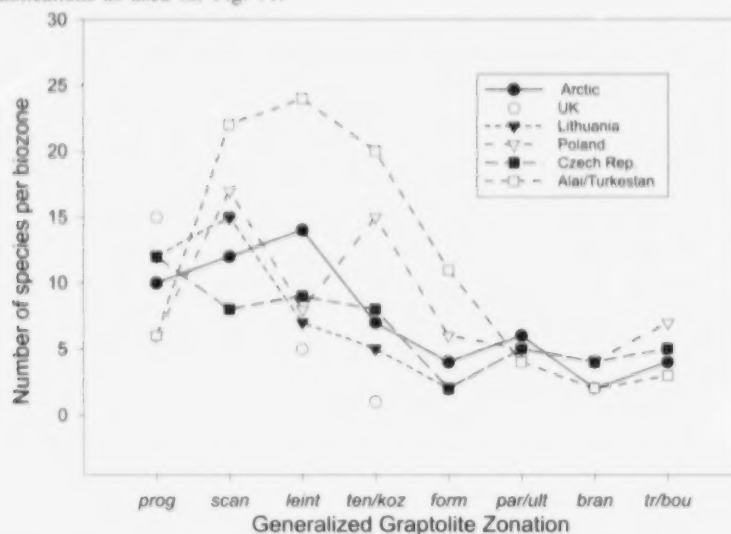
Figure 11 shows the current Ludlow-Pridoli biostratigraphic sequence from the Arctic, and proposes a correlation with biostratigraphic schemes from other regions in the world, predominantly within the Northern Hemisphere. It will be readily apparent that in comparison with Ludlow biostratigraphic zones of, particularly, the Czech Republic (Štorch 1995), Poland (Urbanek 1997a), the Tien Shan region of Central Asia (Koren' 1983; Koren' and Sujarkova 1997), and Ukraine (Tsegelnyuk 1976), the Arctic biozonal sequence is impoverished, particularly in the Upper Ludlow interval where, for example, the *bohemicus tenuis* - *praecornutus* and *formosus* biozones of the Arctic correspond to four and nine biozones of the Czech Republic and Poland, respectively. As a result, correlation of, especially, the Upper Ludlow may be somewhat imprecise. The sparseness of fauna in the Upper Ludlow is puzzling, since it is clear that Upper Ludlow rocks are present in abundance. For example, in the Baillie Hamilton carbonate-rich section (Fig. 2, section 6), the post-*linearis-ceratus* Biozone and pre-Pridoli in-

terval is at least 200 m thick, and at Cape Sir John Franklin (Fig. 2, section 9), a shale-rich sequence, the same biostratigraphic interval is about 100 m thick. In both instances, as well as in other sequences, the Upper Ludlow rocks yield few or no graptolites, and what few are present are long-ranging species. It may be significant that in the Baillie Hamilton section, the Upper Ludlow part of the sequence is predominantly dolostone, or at least dolomitic, rather than the limestones seen lower in the section, and that debris flows, or chaotic beds or bands are fairly common. In a few cases, platy bed-fragments in debris flows are imbricated. By comparison, in the apparently deeper water sequences such as that at Abbott River, the black, evenly bedded shales and occasional concretion-bearing carbonate bands of the Lower and Middle Ludlow give way to almost entirely black shales in the Upper Ludlow. In at least the former case, a shallowing event is suggested, although why that alone should exclude graptolites, or other faunas such as radiolarians, is not understood (see discussion below).

Fig. 11. Arctic biostratigraphic zonation and proposed correlation of Arctic biozones with those from the British Isles, Czech Republic, Poland, Tien Shan (Central Asia), and Lithuania.

		ARCTIC CANADA (this paper)	BRITISH ISLES Rickards 1976	CZECH REP. Jaeger 1986 Štorch 1995	POLAND Urbanek & Teller 1997	TIEN SHAN Koren' 1983, 1986, 1993	LITHUANIA Paskevičius 1979
PRIDOLI		<i>birchensis</i> <i>transgrediens</i>	No graptolites	<i>transgrediens</i>	<i>transgrediens</i>	<i>microdon</i> <i>aksajensis</i>	?
		<i>bouceki</i>		<i>perneri</i> <i>beatus</i>	<i>perneri</i>	<i>perneri</i> <i>kazakhstanensis</i>	
		<i>branikensis</i>		<i>bouceki</i>	<i>bouceki</i>	<i>bouceki</i>	
		<i>ultimus</i>		<i>lochkoviensis</i> <i>pridoliensis</i>	<i>lochkoviensis</i> <i>-branikensis</i>	<i>lochkoviensis</i> <i>-beatus</i>	
		<i>parultimus</i>		<i>ultimus</i> <i>parultimus</i>	<i>ultimus</i> <i>parultimus</i>	<i>pridoliensis</i> <i>-ultimus</i> <i>formosus</i> <i>-bessobaensis</i>	
LUDLOW	LUDFORDIAN	<i>formosus</i>	<i>bohemicus</i> <i>tenuis</i>	<i>fragmentalis</i> <i>latilobus</i>	<i>spineus</i> <i>acer</i> <i>latilobus</i>	<i>formosus</i> <i>-spineus</i>	<i>formosus</i>
		<i>bohemicus</i> <i>tenuis</i> <i>praecornutus</i>		<i>kozłowski</i> <i>inexpectatus</i>	<i>kozłowski</i> <i>inexpectatus</i>	<i>kozłowski</i>	<i>balticus</i>
	GORSTIAN	<i>linearis</i> <i>-ceratus</i>	<i>leintwardin</i> <i>-ensis</i> <i>tumescens</i>	<i>linearis</i>	<i>auriculatus</i> <i>cornutus</i> <i>praecornutus</i> <i>aversus</i> <i>hemiaversus</i> <i>invertus</i>	<i>cornutus</i> <i>-podoliensis</i>	<i>tauragensis</i> (= <i>dalejensis</i>)
		<i>scanicus</i>	<i>scanicus</i>	<i>chimaera</i>	<i>parascanicus</i>	<i>leintwardiensis</i>	
		<i>progenitor</i>	<i>nilssoni</i>	<i>colonus</i>	<i>progenitor</i> <i>nilssoni</i>	<i>scanicus</i> <i>-chimaera</i> <i>nilssoni</i> <i>-colonus</i>	<i>scanicus</i> <i>progenitor</i> <i>nilssoni</i>

Fig. 12. Ludlow and Pridoli zonal species diversity using the Generalized Graptolite Zonal sequence of Koren' et al. (1995). *prog.*, *progenitor* Biozone; *scan.*, *scanicus* Biozone; *leint.*, *leintwardinensis* Biozone; *ten/koz.*, *tenuis/kozłowski* Biozone; *form.*, *formosus* Biozone; *par/ult.*, *parultimus/ultimus* Biozone; *bran.*, *branikensis/lochkoviensis* Biozone; *tr/bou.*, *transgrediens/bouceki* Biozone. Species diversity data retrieved from same publications as used for Fig. 11.



A global comparison of zonal species diversity is shown in Fig. 12. It should be pointed out, however, that for the sake of uniformity, the Generalized Graptolite Zonation scheme of Koren' et al. (1995) is used, and as a result, the combined four Upper Ludlow biozones of the Czech Republic and corresponding nine biozones in Poland are treated as equivalent to the *tenuis-kozłowski* and *formosus* biozones of

the Generalized Graptolite Zonation scheme. The greatest differences in zonal species diversity among the various regions considered lies within the Ludlow, whereas that of the Pridoli is rather more uniform.

The low species diversity of the Ludlow and, in particular, the Upper Ludlow of the Canadian Arctic Islands, as well as that of northern Yukon (Lenz 1988), relative to that in

Table 1. Geographic distribution of the more common and widespread species of Ludlow monograptids.

	Arctic Islands	Yukon	Poland	Czech Rep.	Central Asia	UK	Ukraine
<i>N. nilssoni</i>			x	x	?	x	?
<i>L. progenitor</i>	x	x	x	x	x	x	x
<i>C. colonus</i> group	x	x	x	x		x	x
<i>C. roemeri</i>				x	x	x	x
<i>S. varians</i>	x	x		x		x	x
<i>S. leintwardinensis</i>			x	x	x	x	
<i>S. chimaera</i>			x	x	x	x	x
<i>S. linearis</i>	x	x		x	x		x
<i>B. b. bohemicus</i>	x	x	x	x	x	x	x
<i>B. b. tenuis</i>	x	x	x	x	x	x	x
<i>B. garratti</i>	x	x		x			
<i>B. praecornutus</i>	x	x	x	x	x		?
<i>B. cornutus</i>		x	x	?	x		
<i>L. scanicus/parasc.</i>	x		x	x		x	x
<i>L. invertus</i>			x		x		
<i>Cuc. hemiaversus</i>			x		x		x
<i>Cuc. aversus</i>			x		x		x
<i>Neolob. auriculatus</i>			x		x		
<i>Neoc. inexpectatus</i>			x	x	x		x
<i>Neoc. kozlowskii</i>			x	x	x		
<i>M. uncinatus</i>	?		x	x	?	x	
<i>M. ceratus</i>	x	x					
<i>M. micropoma</i>			x	x		x	
<i>M. balticus</i>		x	x		x		x
<i>M. acer</i>			x				x
<i>M. protospineus</i>			x				
<i>M. spineus</i>			x		x		x
<i>M. beatus</i>	?				x		
<i>Pol. egregius</i>			x	x			
<i>Pol. podoliensis</i>				x	x		
<i>Ps. dalejensis</i>	x	x	x	x	x		x
<i>Ps. latilobus</i>			x	x	x		x
<i>Ps. fragmentalis</i>	x		x	x	x		
<i>F. formosus</i>	x	x	x	x	x		x

Note: Species data from same sources as used for Figs. 11 and 12. *N.*, *Neodiversograptus*; *C.*, *Colonograptus*; *S.*, *Suctograptus*; *B.*, *Bohemograptus*; *L.*, *Lobograptus*; *M.*, *Monograptus*; *F.*, *Formosograptus*; *Ps.*, *Pseudomonoclimacis*; *Cuc.*, *Cucullograptus*; *Neolob.*, *Neolobograptus*; *Neoc.*, *Neocucullograptus*; *Pol.*, *Polonograptus*.

Poland (Tomczyk et al. 1991; Urbanek and Teller 1997; Urbanek 1997a), the Czech Republic (Přibyl 1983; Štorch 1995), Central Asia (Koren' 1983, 1986, 1993; Koren' and Sujarkova 1997), and the Ukraine (Tsegelnyuk 1976), is very puzzling. Firstly, and most striking, is the absence in the Arctic of many Upper Ludlow species of true *Monograptus*, for example, *M. acer*, *M. balticus*, *M. protospineus*, and *M. spineus*. Secondly, and even more striking, is that with the exception of *Lobograptus scanicus* and *L. parascanicus* in the Lower Ludlow, there is a total absence of all neolobograptids, cucullograptids, and neocucullograptids higher in the Arctic Ludlow sequence. Thus, in comparison with the Upper Ludlow sequences of central Europe and Central Asia, the Arctic faunas are depauperate not only in species content, but also in several morphotypes that are present elsewhere; i.e., there is both a quantitative and qualitative disparity between the Canadian Arctic and Cordillera and the other regions of the world. This is clearly shown in Ta-

ble 1 that comprises a list of many of the more common and widely distributed Ludlow monograptid species comparing the species occurring in the Arctic with those from several regions of the world. On the other hand, the Arctic appears to have been a region of minor, but unique, proliferation of the genus *Pseudomonoclimacis*; that is, along with the widespread and very variable species *P. dalejensis dalejensis*, there occur apparently endemic species *P. dalejensis rectus* n. subsp., *P. brevicucullus* n. sp., and *P. hispinosus*. Furthermore, although several species of the genus *Bohemograptus* are common in the Arctic, its probable descendant *Polonograptus*, so well represented in the Czech Republic and Podolia (Štorch 1995) and to a lesser extent in Australia (Rickards and Wright 1999a), is totally absent.

The lack of both species and morphotype diversity in the Arctic and northern Canada is difficult to explain, but may have been due to some type of environmental exclusion, such as occupying differing depths in the water column, or

to a physical barrier to immigration from other regions of the world. Wilde et al. (1991), in their reconstruction of Silurian oceanic circulation, place Siberia close to or attached to the northern side of Laurentia and projecting to almost 60° north latitude during the Ludlow. They show the north tropical current skirting the northern (tropical) side of Gondwanaland and Kazakhstan, swinging northwards along the eastern side of Laurentia and Siberia (see Fig. 13) and eventually linking up with an eastward flowing polar current. Although the continuation of this current eventually brings it down the west side of Siberia and Laurentia the waters bathing those regions would initially have been cool. At the same time waters from the tropical currents bathing eastern Laurentia and Baltica might have been barred from the western and northwestern parts of Laurentia by the periodically positive Trans-Continental Arch. This feature, and the fact that the Late Ludlow appears to have been a time of shallowing in at least the Canadian Arctic and northern Yukon (as suggested by the notable increase in dolomite in some carbonate-dominated sections, and the paucity and consistently low diversity of the graptolite faunas everywhere in the Arctic Upper Ludlow) might explain the absence of many of the species that are present in Baltica. Note also that Melchin et al. (1998) suggest a global regression during most of the Late Ludfordian (late Silurian). If this scenario is even partially correct, northern and Arctic Canada and its extension south into at least the northern Cordillera could have been a type of "backwater" in which only endemics and those species capable of withstanding cool and, possibly, relatively shallow waters, would commonly occur. As a modern-day comparison, and as some support for these suggestions, Norris (2000) shows that even in "open" ocean regions of the world, unfettered migration of species is prevented by changes, some seasonal, in the relatively local but sometimes long-lasting water masses that

readily form, leading to discontinuous distributions of pelagic organisms.

Retiolitids, while fairly common and relatively diverse in species up to the mid-Ludlow, have received only scant attention from a biogeographic viewpoint. The reasons for this are threefold: first, many retiolitids are notoriously difficult to identify in flattened form, and their preservation as isolated, uncompressed forms in carbonates that range through a considerable part of the Silurian is exceedingly rare outside of Arctic Canada and the Baltic region, including northeastern Poland; second, and with few exceptions such as the studies of Eisenack (1951) and Obut and Zaslavskaya (1983), it is only since the advent of the SEM and its use to study isolated retiolitids that there have been many advances in understanding retiolitid morphology and taxonomy; and third, the vast majority of retiolitids species described in recent years have been those preserved in isolated, uncompressed form, resulting in an almost order of magnitude increase in the number of presently known Ludlow retiolitid species. Prior to these studies, for example, only *Spinograptus spinosus*, *Plectograptus macilentus*, and *Holoretiolites mancki* were commonly and widely known (e.g., Wood 1900, Münch 1931, Eisenack 1951, Bouček and Münch 1952), whereas at least 19 species of six genera are now recognized from Arctic Canada (this study) and northeastern Poland (Kozłowska-Dawidziuk 1995, 1997) alone (see Fig. 14).

Thus, meaningful comparisons are possible between only two places in the world — Arctic Canada (this paper) and Poland (Kozłowska-Dawidziuk 1995, 1997, 2002) — both of which yield isolated, beautifully preserved graptolites from stratigraphically continuous sequences (Fig. 14). A proliferation of new retiolitid genera and species, particularly of the genus *Neogothograptus*, began in the earliest Ludlow *progenitor* time interval accompanied by the continuation of

Fig. 13. Late Silurian (Ludlow) continental configuration and suggested major ocean currents. Modified and simplified from Wilde, Berry, and Quinby-Hunt (1991). Note the cold-water current moving down the western side of Siberia and the northwestern side North America.

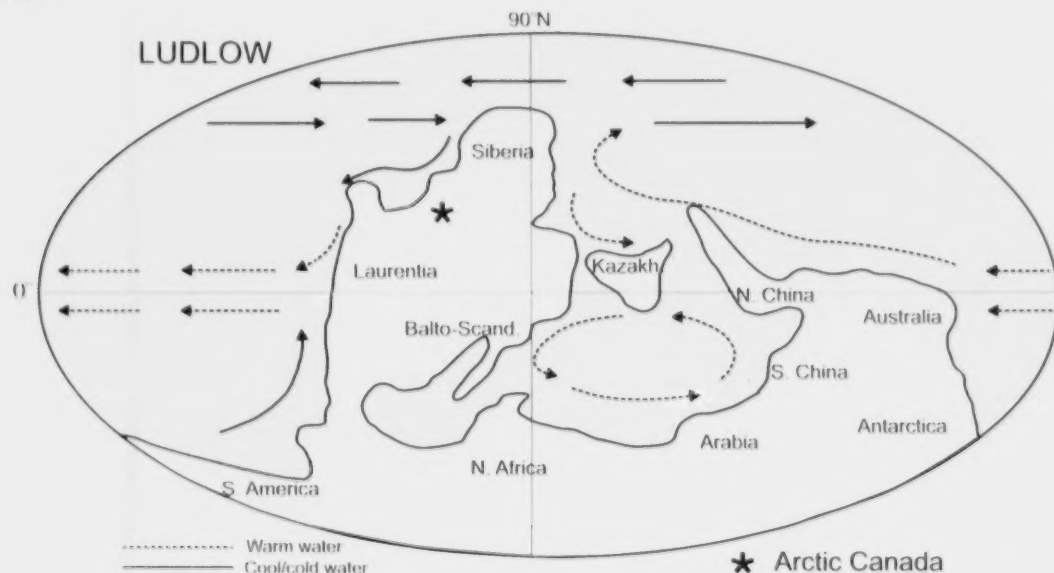


Fig. 14. Comparison of species occurrences of Ludlow retiolitids in Arctic Canada with those of northeastern Poland. Biozonal boundary correlations are approximate.

Arctic Canada		Northeastern Poland	
linearis-ceratus Biozone	<i>Spinograptus spinosus</i> <i>Spinograptus clathrospinosus</i> <i>Neogothogr. purus labiatus</i> <i>Neogothograptus</i> sp.	hemiaversus Biozone	<i>Plectodinemagraptus gracilis</i> <i>Holoretiolites manckoides</i>
		parascanicus Biozone	<i>Holoretiolites atrabecularis</i> <i>Holoretiolites mancki</i> <i>Holoretiolites erraticus</i> <i>Semiplectograptus urbaneki</i> <i>Plectograptus macilentus</i>
scanicus Biozone	<i>Holoretiolites manckoides</i> <i>Neogothograptus alatifomis</i> <i>Neogothogr. purus labiatus</i> <i>Plectograptus macilentus</i> ?	progenitor Biozone	<i>Plectograptus macilentus</i> <i>Neogothograptus romani</i> <i>Neogothograptus balticus</i> <i>Neogothograptus</i> sp.
progenitor Biozone	<i>Spinograptus spinosus</i> <i>Spinograptus clathrospinosus</i> <i>Spinograptus quadratus</i> <i>Holoretiolites manckoides</i> <i>Holoretiolites atrabecularis</i> <i>Neogothograptus alatifomis</i> <i>Neogothograptus melchini</i> <i>Neogothogr. thorsteinssoni</i> <i>Neogothogr. purus labiatus</i> <i>Plectograptus macilentus</i> <i>Plectograptus robustus</i>	nilssoni Biozone	<i>Neogothograptus purus purus</i> <i>Plectograptus macilentus</i> <i>Plectograptus wimani</i> <i>Spinograptus spinosus</i> <i>Spinograptus clathrospinosus</i> <i>Spinograptus munchi</i>

Spinograptus spinosus, *S. clathrospinosus*, and *Plectograptus macilentus* from the latest Wenlock. In Arctic Canada four genera containing 11 species occur in the lowest biozone, but it is only the three long-ranging species noted above that occur in common with the earliest species in Poland. In Poland six species of retiolitids occur in the *nilssoni* Biozone, but the fauna is dominated by species ranging up from the underlying upper Homerian: *Spinograptus* (*S. munchi*, *S. clathrospinosus*, *S. spinosus*) and *Plectograptus* (*P. wimani*, *P. macilentus*) accompanied by one new genus and species, *Neogothograptus purus*. In the overlying *progenitor* Biozone four species, including two new species of *Neogothograptus* (*N. balticus*, *N. romani*) occur. If, as suggested in the biostratigraphy section, the *progenitor* Biozone of Arctic Canada is correlative with the combined *nilssoni* and *progenitor* biozones in Poland, then the two regions share only the three long-ranging species, *S. spinosus*, *S. clathrospinosus*, and *P. macilentus*, and the remaining 16 are different.

The *parascanicus scanicus* Biozone of each region further reflects the striking difference. Of the species present (five in Poland and four in Arctic Canada), only one species, *Plectograptus macilentus*, is common to both, and in Poland, a new genus *Semiplectograptus* appears.

The *hemiaversus* Biozone in Poland, the approximate correlative of the *ceratus linearis* Biozone of the Arctic, contains *Plectodinemagraptus gracilis*, a new taxon with the smallest size and greatest reduction of the skeletal structure of any known retiolitid, and *Holoretiolites manckoides*, a species already appearing in the *scanicus* Biozone in Arctic Canada. By contrast, the four species recognized in the *linearis-ceratus* Biozone of Arctic Canada, comprise the same species of *Spinograptus* and *Neogothograptus* occurring in the two underlying biozones. All in all, strong endemism is suggested.

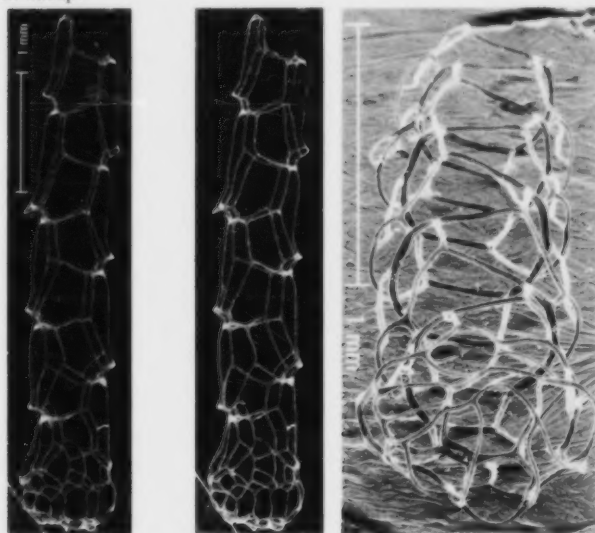
The evolution of Ludlow retiolitids in Arctic Canada and Poland appears to have followed different paths. In Arctic

Canada retiolitids seem to show little in the way of an orderly evolution through their range in the Ludlow, and seem more characterized by a very early proliferation of species of a few genera, in particular those of *Neogothograptus*. This could be the result of limited connections with contemporary faunas elsewhere, resulting in semi-isolation and rapid evolution in the earliest Ludlow, such as is suggested for the monograptids. In the East European Platform part of Poland, by contrast, evolution appears to have proceeded in a rather more stepwise manner with new forms occurring in succeeding biozones, and showing trends such as decreasing size of rhabdosomes, and reduction of the ancora sleeve and number of thecae.

The limited comparative data from the upper Wenlock (Lenz and Kozłowska-Dawidziuk 2001b, 2002) and the Ludlow of Arctic Canada and northeastern Poland and the general eastern Baltic region presented here thus suggest that retiolitids possess some considerable biogeographic potential. However, elsewhere, as in southern Yunnan, China, and based on a single, limited study, unidentified species of *Neogothograptus* and *Holoretiolites* occur in Ludlow rocks (Zhang and Lenz 1997), a species very close to *Neogothograptus alatifomis* sp. nov., is present (see Fig. 15), and *Papiliograptus papilio* Lenz and Kozłowska-Dawidziuk is almost certainly represented in the underlying upper Homerian rocks (identified as "*Agastograptus* sp. 1"). Thus, more detailed studies focussed heavily on retiolitids are required in order to fully evaluate their biogeographic potential.

Biogeographic differences in the Pridoli are less striking in most parts of the world, although they are still present in some regions, and mainly at the species level, as exhibited by the unique occurrence of species such as *Neocolonograptus norfordi* and *Bohemograptus? helicoides* in both the Arctic and Yukon. Common biozonal index species such as *Neocolonograptus parultimus*, *N. ultimus*, *N. branikensis*, *N. transgrediens*, and *Monograptus bouceki* are, however, more or less universally present, and unlike the situation in the

Fig. 15. *Neogothograptus purus purus* Kozłowska-Dawidziuk 1995, type number ZPAL G.35/1. Note the lack of thickened apertural lips, the primary feature that distinguishes it from *Neogothograptus purus labiatus* Lenz and Kozłowska-Dawidziuk, n. subsp.



Ludlow, all monograptid morphotypes occurring elsewhere are also present in the Arctic. Common species and morphotypes not recognized in the Arctic (and Yukon) are relatively few, but include important "index" species such as *N. loch-*

koviensis, *Monograptus pridoliensis*, and *M. perneri*, all of which are present in the Czech Republic, Poland, and Central Asia.

In comparison with Central Asia (Koren' 1983, 1986, 1993; Koren' and Sujarkova 1997) and adjacent Xinjiang, westernmost China (Ni et al. 1998), however, the differences are much more striking, primarily due to the large number of species of *Monograptus* recorded: *M. beatus*, *M. prognatus*, *M. mironovi*, *M. microdon aksajensis*, *M. balaensis*, *M. anerosus*, *M. supinus*, *M. willowensis*, and *M. perneri kazakhstanensis*, many of which are endemic, as well as a number of unique pristiograptid and pseudomonilimacis species in those regions. Of this fauna, *M. beatus* and *M. prognatus* have been recognized in the Barrandian region (Jaeger 1986), and other species such as *M. bessobaensis* and a form close to *Monograptus beatus* occur in the uppermost Ludlow and uppermost Pridoli of the Arctic, respectively. A species from the Ludlow close to or identical with *M. anerosus*, and described as *M. banksi* by Rickards et al. (1995), has been reported from Australia, and a single specimen tentatively identified as *M. anerosus* has been found in the Upper Pridoli in northern Yukon (Lenz 1988). A further species, *M. willowensis*, first described from Nevada (Berry and Murphy 1975) is also found in Central Asia. Finally, *Monograptus microdon*, a fairly common species in central Europe (Jaeger 1959), is represented in Central Asia (Koren' 1983) by the subspecies *M. microdon aksajensis*, and in the Arctic by the new subspecies, *M. microdon curvatus*. Of these species, only *M. microdon aksajensis* is known, with certainty, to occur in the Upper Silurian.

Evolutionary developments in Ludlow and Pridoli graptolites

Following the profound extinction event at the end of the early Homerian (the "Grosse Krise" of Jaeger 1991 or "lundgreni extinction event" of Koren' 1991; see Lenz and Kozłowska-Dawidziuk 2001b), and the modest recovery through the latest Wenlock, late Homerian (see Lenz and Kozłowska-Dawidziuk 2002), the earliest Ludlow was marked by a relatively rapid evolutionary "burst" among the monograptids, and to a lesser extent among the retiolitids (Lenz and Kozłowska-Dawidziuk 2002). The diversification among the monograptids not only involved a strong increase in genus/species diversity, but also showed a pronounced increase in morphological diversity. For example, the genera *Lobograptus* and *Colonograptus*, represented in the upper Homerian by species such as *Lobograptus sherrardae* and *Colonograptus ludensis*, respectively, were succeeded by species such as *L. progenitor* and *C. colonus* and the closely related *Saetograptus*. In the latter genus, the upper Homerian forms bearing relatively modest lappets (basically derivations and elaborations of simple *Pristiograptus dubius* forms; see, for example, Rickards and Wright 2003) were replaced by forms with strongly developed and, often, spine-like lappets in the Ludlow. In like manner, the simple thecae of the *Lobograptus*-related forms of the upper Homerian were subsequently transformed into species with complex to very complex and asymmetrical metathecal structures

through the Ludlow, beginning with species such as *L. progenitor* and *L. scanicus* and continuing on and becoming more complex in succeeding species (see Urbanek 1966, 1997a). On the other hand, the relatively complex siculae (flaring apertures, well-developed dorsal tongue) present in some upper Homerian species such as *Colonograptus deubeli*, *C. ludensis*, *Lobograptus sherrardae*, and *L. claudiae* did not cross the boundary and did not reappear until about the mid-Ludlow (e.g., *Saetograptus linearis*). Similar progressions in the morphological developments of siculae from simple to complex are witnessed several times in the higher Ludlow and through the Pridoli, each time independently "re-inventing" the structure as a new feature.

Monograptus (s.s.) and *Monoclimacis* that were common in the lower Homerian, and rare or absent in the upper Homerian ("Lazarus" taxa?), reappear globally in the form of species such as *M. uncinatus* and *Pseudomonclimacis* spp. Species of *Monograptus* become more common up the stratigraphic column, are the dominant taxa in the uppermost Ludlow, and persist through to their final extinction near the end of the Early Devonian. *Pseudomonclimacis*, on the other hand, while fairly common in the middle and upper Ludlow, disappears prior to the close of the Ludlow (see Urbanek and Teller 1997). The *Bohemograptus* group appeared in the earliest Ludlow, and species such as *B. bohemicus bohemicus*

and *B. bohemicus tenuis* are extremely common and widespread globally. Subsequent younger species, such as the lower Ludfordian species *B. praecornutus*, *B. cornutus* Urbanek, 1970, *B. paracornutus* Rickards and Wright, 1999b, and various species of *Polonograptus*, display extremes of sicular and thecal development (see Urbanek 1970, Štorch 1995, Rickards and Wright 1999b). The cucullograptids and neocucullograptids are extremely interesting groups and, although separated in time and most probably independently derived, demonstrate similar, convergent histories. Both groups appear to derive independently from ancestors with a relatively simple thecal morphology, and through time, their apertural regions become increasingly complex, with strong tendencies toward asymmetry in the apertural lobes and, ultimately, spine-like rostral processes (Urbanek 1966, 1970, 1996; Urbanek and Teller 1997). As already noted above, these forms are virtually absent from the Arctic.

The monograptid faunas of the Pridoli are relatively low in diversity, compared with those of the Ludlow (Melchin, et al. 1998), are dominated by representatives of *Monograptus* and *Neocolonograptus* (Urbanek 1997a), and show little similarity to the latest Ludlow representatives, although forms such as *Monograptus bessobaensis* may cross the boundary in the Arctic (see Fig. 10). The *Neocolonograptus* group is particularly interesting in that it appears independently twice during the Pridoli: i.e., the earlier *ultimus* group and the later *transgrediens* group (see Urbanek 1997a). Particularly in the case of the earlier subgroup, there is a marked development from simpler to more complex thecal morphology up the stratigraphic column (i.e., *Neocolonograptus parultimus* to *Neocolonograptus ultimus* to *Neocolonograptus branikensis/lochkoviensis*). The evolutionary history of the Ludlow and Pridoli monograptids may be summarized as follows:

1. Tendency in some clades to increase in morphological complexity through their stratigraphic ranges; e.g., *Bohemograptus* and *Lobograptus* during the early to mid-Ludlow; *Cucullograptus* in the mid-Ludlow; *Neocucullograptus* in about mid-Ludfordian; *Neocolonograptus* through the early to mid-Pridoli.
2. Evolutionary convergence in the thecal structures of some time-separated lineages; e.g., *Cucullograptus* versus *Neocucullograptus*; and *ultimus* group versus the *transgrediens* group.
3. Rapid changeovers at particular levels, with commonly little similarity between taxa before and after the interval, and corresponding to the "bioevents" of Urbanek and Teller (1997), who recognize four bioevents in the Ludlow-Pridoli interval. These bioevents were followed by independent mainstream developments, essentially "re-inventions" or iterations, each derived from the simple, but very long-ranging *Pristiograptus dubius* group, and each basically becoming more complex up the stratigraphic column (Urbanek 1997a; Rickards and Wright 2003).

4. Tendency toward repeated, or iterative, but independent convergences in sicular morphology. The development patterns of strongly flaring apertures and pronounced dorsal tongues first "invented" in late Homeric taxa, such as *Colonograptus deubeli* and *Lobograptus sherardae*, is "reinvented" in the siculae of several species of *Sactograptus* and the *Bohemograptus* lineages of the early to mid-Ludlow, the *Monograptus acer* group of the Ludlow, the *ultimus* group of the early Pridoli, and the *transgrediens* group of the late Pridoli.

The biostratigraphic ranges of the retiolitid group within the Ludlow were relatively short, the greatest species diversity being in the early Ludlow *nilssoni/progenitor* and *scanicus* intervals, followed by a lesser diversity in the mid-Ludlow, *leintwardinensis/linearis* time interval, and becoming extinct shortly thereafter. Unlike the monograptids, several taxa cross the Wenlock-Ludlow boundary interval; these include *Spinograptus spinosus* and *S. clathrospinosus*, and *Plectograptus macilentus* among others (see Kozłowska-Dawidziuk 1995, Lenz and Kozłowska-Dawidziuk 2002). *Gothograptus* (s.s.) disappeared prior to the end of the Wenlock, and its presumed descendant, *Neogothograptus*, appeared in the earliest Ludlow, underwent fairly rapid evolution, and subsequently gave rise to *Holoretiolites*. Within the *Plectograptus* lineage (Kozłowska-Dawidziuk 2001), *Semiplectograptus* and *Plectodinemagraptus*, represent the youngest known retiolitids, the latter occurring in the middle Ludlow, *hemiaversus* Biozone.

Evolutionary trends within the retiolitids include the following. (1) A pronounced diversity decrease, from highest in the *nilssoni/progenitor* chrons to only two species, including the newly appearing *Plectodinemagraptus*, in the mid-Ludlow, *Cucullograptus hemiaversus* chron. (2) Generally speaking, there is a size decrease up the stratigraphic column, with such (relatively) large taxa as *Plectograptus macilentus*, *P. wimani*, *Spinograptus spinosus*, and *S. clathrospinosus* occurring much more commonly in the lowest biozones of the Ludlow, and very small taxa such as *Plectodinemagraptus*, *Semiplectograptus*, and some species of *Holoretiolites*, higher up the sequence (see Kozłowska-Dawidziuk and Lenz 2001). (3) The occurrences of spine-like or spino-reticular structures, or simple to complex genicular structures, as in *Spinograptus spinosus* and *S. clathrospinosus*, *Plectograptus wimani*, and *Neogothograptus alatifomis* n. sp., are more common in the lower Ludlow, although they do range higher. In some cases, as in *Spinograptus clathrospinosus* or *Neogothograptus alatifomis* n. sp., the spinoreticular structures reach relatively enormous sizes. (4) A general decrease in morphological complexity up the stratigraphic column, notably accompanied by a strong tendency toward a loss of the ancora sleeve, as in *Plectodinemagraptus* and *Holoretiolites* and even a decrease in the amount of thecal framework as in *Plectodinemagraptus* (see Kozłowska-Dawidziuk 1995, Kozłowska-Dawidziuk and Lenz 2001) is evident.

Systematic paleontology

All figured specimens described in this publication are housed in the National Type Collection of Invertebrate and Plant Fossils of the Geological Survey of Canada (GSC), Ottawa, Ontario, K1A 0E8, and are assigned GSC numbers. Retiolitid morphological terms follow those used in Lenz and Kozłowska-Dawidziuk (2001*b*, p. 7). Throughout the Systematics section, no attempt has been made to show complete synonymies; rather, only those considered to be more important are listed.

Abbreviations of section localities are as follows (see also Appendices): AB, Abbott River; BH, Baillie Hamilton; CP, Cape Phillips; GP, Grant Point; HH, Humphries Hill; IB, Irene Bay; MCM, Cape Manning area; RC, Rookery Creek; SB and SBC, Snowblind Creek; SF, Strathcona Fiord; SJF, Cape Sir John Franklin; TW, TWN, and TWW, Twilight Creek.

The mid-level classification for the monograptids and retiolitids follows that used by Melchin (1998).

Class GRAPTOLITHINA Bronn, 1846

Order DENDROIDEA Nicholson, 1872

Genus *Dictyonema* Hall, 1851

Type species. *Gorgonia retiformis* Hall 1843, p. 115.

Dictyonema sp.

Pl. 1, figs. 1, 8

Description. Stipe fragments only. Autothecae relatively short, in a single row on one side of stipe. Thecal apertural processes long, bifurcating, tongue-like. Bithecae lateral to, and about level with, apertures of autothecae; occasional bitheca along lateral wall about midway between two autothecal apertures. Dissepiments fragmentary only, spaced about every second theca.

Study material. One fragment from SBC-8E.

Genus *Acanthograptus* Spencer, 1878

Type species. *Acanthograptus granti* Spencer, 1878, p. 461.

Acanthograptus? sp.

Pl. 1, figs. 2, 13

Description. Rhabdosomal branch fragments with more or less zigzag pattern, rope-like in cross-section, with autothecae rather irregular in pattern, more or less alternating and tube-like, free for about 0.5 mm. Bithecae not clearly shown.

Study material. One fragment from SB97, A43.5 m.

Genus *Thallograptus* Ruedemann, 1925

Type species. *Dendrograptus? succulentus* Ruedemann, 1904, p. 581.

Thallograptus? sp. 1

Pl. 1, figs. 3, 4

Description. Rhabdosomal fragments more or less round in cross-section, straight to slightly zigzag. Autothecae apparently long, tube-like extensions, strongly overlapping, ori-

ented almost 180° around the stipe wall. Cross-sectional view of stipe shows a cluster of thecae (pl. 1, fig. 4). Bithecae unclear, apparently along lateral walls of autothecal tubes and in notch at base of free part of autothecae.

Study material. One fragment from SB97, A4.5 m.

Thallograptus? sp. 2

Pl. 1, figs. 5, 10

Description. Large, robust fragment with broad zigzag pattern, round in cross-section. Autothecae more or less tube-like, arranged on 180° of the stipe. Bithecae numerous, scattered liberally around stipe, diameter almost as great as that of autothecae.

Study material. One well-preserved fragment from BH2-98, 146.5 m.

Thallograptus? sp. 3

Pl. 1, fig. 9

Description. Stipe fragment ropy and moderately zigzag. Autothecae regularly alternating left and right, diverging at about 60° from each other. Bithecae single or paired about halfway between autothecae, about half diameter of autothecae.

Study material. One fragment from SB97, D#1.

Thallograptus sp. 4

Pl. 2, figs. 8-14

Description. Stipe fragments ropy and straight to weakly zigzag, robust branches, branching apparently at irregular intervals. Autothecae tube-like and round, as much as 0.5 mm free of stipe, commonly more concentrated about 180° around stipe. Bithecae irregular, at or near base of autothecae, but also scattered around stipe, less than half the diameter of autothecae.

Study material. Eight fragments, most well-preserved, from RC01-1, 22 m.

Genus *Dendrograptus* Hall, 1858

Type species. *Graptolithus hallianus* Prout, 1851, p. 189.

Dendrograptus sp.

Pl. 1, figs. 11, 12

Description. Stipes straight, branching, round in cross-section. Autothecae arranged in a linear pattern. Apertural processes tongue-like, projecting distally. Bithecae single or in pairs, positioned lateral to and level with or midway between two successive autothecae, about half diameter of autothecae.

Study material. One branching fragment from BH2-98, 71 m.

Dendroid indet.

Pl. 1, figs. 6, 14

Description. Autothecae very long, and strongly overlapping, arranged linearly, tube-like, inclined 30°–40° to stipe axis. Bithecae positioned along autothecal walls, or near base of free part of autothecae.

Study material. One single branch fragment from SB97, A4.5 m.

Order TUBOIDEA Kozłowski, 1938

Genus *Epigraptus* Eisenack, 1941

Type species. *Epigraptus bidens* Eisenack, 1941, p. 24.

Epigraptus? sp.

Pl. 1, fig. 7

?2001b *Epigraptus*? sp., Lenz and Kozłowska-Dawidziuk, p. 8, figs. 3, 5, 6.

Description. Thecorhiza not preserved, so it is unclear whether autothecae arise individually. Autothecae long tubes, possessing elaborate apertural structures. Bithecae positioned near base of autothecae.

Study material. Two fragments lacking the thecorhiza from SB97, A4.5 m.

Order GRAPTOLIDEA Lapworth, 1873

Suborder VIRGELLINA Fortey and Cooper, 1986

Superfamily DIPLOGRAPTOIDEA Lapworth, 1873 (*sensu* Mitchell, 1987)

Family RETIOLITIDAE Lapworth, 1873

Subfamily PLECTOGRAPTINAE Bouček and Münch, 1952

Genus *Neogothograptus* Kozłowska-Dawidziuk, 1995

Type species. *Neogothograptus purus* Kozłowska-Dawidziuk, 1995; Baltic erratic boulder 22 from Jarosławiec, Poland.

Diagnosis. See Kozłowska-Dawidziuk, 1995, p. 303.

Species included. *Neogothograptus purus purus* Kozłowska-Dawidziuk, 1995; *Neogothograptus balticus* (Eisenack, 1951), *Neogothograptus romani* Kozłowska-Dawidziuk, 1995, *Neogothograptus alatiformis* n. sp., *Neogothograptus thorsteinssoni* n. sp., *Neogothograptus melchini* n. sp., *Neogothograptus purus labiatus* n. subsp.

Neogothograptus purus labiatus n. subsp.

Pl. 3, figs. 1–12; Pl. 4, figs. 1–11; Pl. 5, figs. 1–9;

Pl. 6, figs. 1–10; Pl. 7, figs. 3, 4, 6, 9, 10;

Pl. 26, fig. 7

1993 *Holoretiolites mancki* Eisenack; Lenz, p. 20, pl. 12, figs. 1–5, 8–12.

Holotype. GSC 125964; pl. 3, figs. 1, 3–12.

Etymology. From Latin *labiatus*, for lipped, referring to the horizontally widened, robust apertural lips.

Diagnosis. Differs from *Neogothograptus purus purus* Kozłowska-Dawidziuk, 1995, in possession of strong and horizontally expanded lips with distinctive paired labiate structures.

Studied material. Isolated material: BH-57.6 m, 50 specimens; BH-82.5 m, 10 fragments; BH2, 145 m, one specimen; BH2, 149 m, 50 specimens; BH2, 153 m, 20 specimens; SB-88, 4–7 m, 20 specimens; SB-90, 5 m, 3 fragments, 2 m, several fragments; SB-97, (–)2 m, 1 fragment with appendix; SB-97, 0.5 m, 15 fragments, 4.5 m, 10 specimens. Flattened material: several specimens from TC-3B.

Description. Rhabdosomes straight, almost parallel-sided with characteristic pattern of regular zigzag thecal framework lists. A longer, but incomplete specimen, contains six pairs of thecae, while a shorter mature rhabdosome contains three pairs of thecae. Width of proximal part of rhabdosome 0.5–0.7 mm; i.e., similar to *Neogothograptus purus purus* (Kozłowska-Dawidziuk 1995, p. 303). Reticulum sparse, usually single lists occurring on ancora sleeve at proximal end of rhabdosome (Pl. 3, fig. 9), and on ventral walls (Pl. 3, figs. 5–7, 9, 12).

Thecal lips strongly thickened with distinctive paired labiate structures, which are readily apparent in oblique view

of specimens (Pl. 3, figs. 1, 11; Pl. 4, figs. 3, 4, 6–8; Pl. 5, figs. 2–5; Pl. 6, fig. 9). The thickness and size of labia vary from small to fairly prominent. They are very distinctive, especially in mature rhabdosomes (Pl. 4, figs. 6, 7). Outer ancora usually not developed, but may appear occasionally as single lists (Pl. 4, fig. 2, 11; Pl. 5, fig. 3).

Short appendix occurs occasionally (Pl. 6, fig. 10), sometimes supported with thick bandages (Pl. 7, fig. 4). Thick ancora is characteristic for mature rhabdosomes (Pl. 6, figs. 4, 5, 8). Short fragment of virgella usually preserved on ancora (Pl. 3, fig. 4; Pl. 5, figs. 7, 9; Pl. 7, fig. 6). Nema not preserved.

Discussion. The characteristic feature of the new subspecies is the horizontally expanded and thickened lips with distinctive paired labiate structures. The size and shape of the rhabdosome is, otherwise, similar to that of *Neogothograptus purus purus* from Poland (see Fig. 15).

Neogothograptus alatiformis n. sp.

Pl. 11, figs. 1–3; Pl. 12, figs. 1–6; Pl. 13, figs. 1–5;

Pl. 14, figs. 1–10; Pl. 15, figs. 1–10;

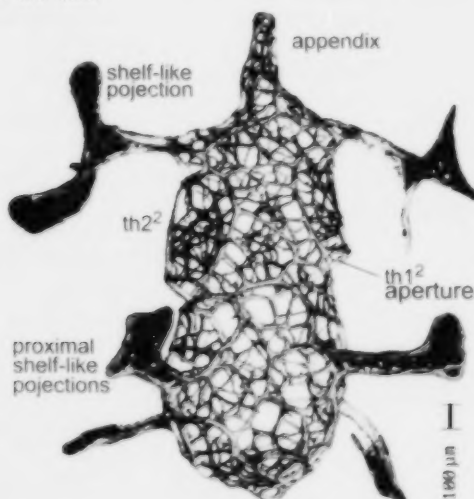
Pl. 16, figs. 1–10

Type. Holotype GSC 125988, Pl. 11, figs. 1–3.

Etymology. From Latin *ala*, wing, for apertural processes forming wing-like structures.

Diagnosis. Small rhabdosomes contain two pairs of thecae and short appendix. Reticulum well developed in mature rhabdosomes, covering both proximal, ventral and lateral orifices. Outer ancora well developed. Two pairs of prominent processes above proximal ventral orifices, proximal to first thecal pair. First pair of thecae without processes, but may have hoods. Second thecal pair with large, opposing paired genicular processes with distally broad, paired, wing-like structures similar to the proximal orifice processes.

Fig. 16. *Neogothograptus alatiformis* Lenz and Kozłowska-Dawidziuk, GSC 125988; outline figure labelling some key skeletal elements.



Studied material. BH2-98, 140 m, many small fragments; 145 m, 15 fragments; 146.5 m, 40 fragments; 147 m, many very small fragments; AB2-99, 22 m, 2 finite rhabdosome and 4 fragments; AB-2 99, 23 m, 6 fragments; TC 711C (C 61679), 40 finite rhabdosomes.

Description. Rhabdosomes small, containing two pairs of thecae and short appendix, total length 1.3–2.2 mm. Reticulum density increases during maturity, and well developed in mature rhabdosomes. Unusually dense and strong reticulum occurs in one specimen (illustrated on Pl. 12, figs. 1, 2), possessing strong single hood on $th\ 1^1$ and single longer process on $th\ 1^2$ with reticulofusellar small lateral hoods on both sides. Reticular lists also cover proximal, ventral, and lateral orifices. Some young rhabdosomes have less reticulum and proximal orifices are more open (Pl. 15, figs. 1, 3, 4, 7–9). Ancora umbrella simple with laterally directed shelf-like projections (Pl. 11, fig. 2; Pl. 12, figs. 5, 6; Pl. 13, fig. 4; Pl. 14, figs. 3–5, 10; Pl. 15, fig. 5), rarely developed as processes (Pl. 11, fig. 2; Pl. 12, fig. 5). Width of ancora umbrella about 0.64 mm; maximum width of rhabdosome on level of proximal ventral processes is 0.66–0.7 mm (measured across mid-ventral lists). Width of rhabdosome may taper gently distally. Outer ancora well developed in all mature specimens (Pl. 15, figs. 1, 2; Pl. 12, figs. 1–6; Pl. 11, figs. 1, 3), appearing in early growth stage of rhabdosome (Pl. 15, figs. 7, 10, 11).

Proximal ventral processes and thecal genicular processes show reticulofusellar nature. Long paired proximal-ventral processes are similar in shape and design to apertural processes on second thecal pair (see Fig. 16). Each process begins as single relatively narrow reticulofusellar list and widens abruptly distally into two-fold, broad, wing-like structures varying in width (Pl. 11, figs. 1–3; Pl. 16, figs. 2, 4, 5). Prominent two paired processes well developed above ventral proximal orifices in all forms (Pl. 11, figs. 1–3; Pl. 12, figs. 5, 6; Pl. 13, figs. 1–5; Pl. 14, figs. 4, 5, 7, 9, 10). There are two morphotypes with different development of thecal genicular processes.

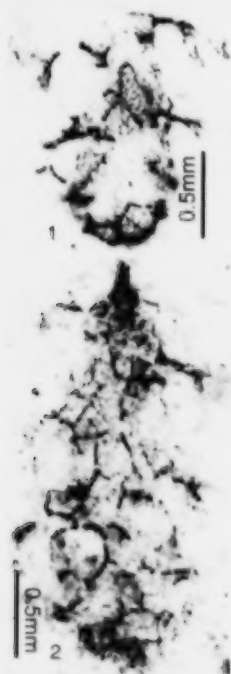
Morphotype A lacks genicular processes on first thecae, but has a single process on each theca of the second pair. The holotype represents morphology A (Pl. 11, figs. 1, 3). Morphotype B develops all lateral paired reticulofusellar hoods on first pair of thecae (Pl. 14, figs. 1–4, 8–10; Pl. 15, fig. 3; Pl. 16, figs. 1–4, 8, 9) on either side of single, prominent processes of second pair of thecae.

Appendix distinctly separated from thecal walls (Pl. 11, figs. 1–3; Pl. 12, figs. 1, 3, 5, 6; Pl. 15, fig. 3), short (up to 250 μ m), tapers noticeably distally resulting in small rounded opening of about 50 μ m in diameter (Pl. 14, figs. 3, 6, 9; Pl. 16, figs. 1, 2, 7–10).

Virgella preserved as short list (Pl. 14, figs. 3, 9; Pl. 15, figs. 9, 11). Nema not preserved, except in one specimen where a small fragment is preserved in distal part of appendix (Pl. 16, figs. 6, 10).

Discussion. *Neogothograptus alatiformis* is one of the smallest retiolitids known. It possesses distinctive processes, which increase the width of the rhabdosome up to three times. These processes are unique to *Neogothograptus*, and a few other retiolitids. Particularly extraordinary are the relatively huge processes in proximal and distal parts of rhab-

Fig. 17. *Neogothograptus* cf. *alatiformis* from the Lower Ludlow, progenitor Biozone from Yunnan, China (= "*Agastograptus* sp. 2" of Zhang and Lenz, 1997). 1. Nanjing Institute of Geology and Palaeontology (NIGP) type number NIGP127831; 2. NIGP137013, an additional specimen selected for this study.



dosome. These processes considerably increased the surface area of the rhabdosome, and presumably served some hydrodynamic function, perhaps serving to keep the colonies at a certain level in the water column. A form similar to *Neogothograptus alatiformis*, and clearly assignable to the genus *Neogothograptus*, was described from China as *Agastograptus* sp. 2 in Zhang and Lenz (1997, fig. 3C). The Chinese forms, however, possess long genicular processes on the first and second pair of thecae (see Fig. 17), whereas in the Arctic Canada forms the processes are present above the proximal orifices and on the second pair of thecae.

Neogothograptus melchini n. sp.

Pl. 17, figs. 1–13

1993 *Holoretolites mancki* Lenz, p. 20, pl. 12, figs. 6, 7.

Type. Holotype GSC 126003, Pl. 17, fig. 4.

Etymology. In honour of M. Melchin, Canadian graptolite worker.

Studied material. MCM-91 (st. 112, 113), 50 larger fragments; MCM 90 (st. 112), 50 specimens; BH-86 m, 10 fragments; SB-97, 1.5 m, 35 specimens; SB-97, 2 m, 20 specimens.

Diagnosis. *Neogothograptus* with mid-ventral lists reduced to short fragments on thecal lips; without reticulum.

Description. The longest rhabdosomes contain three or four pairs of thecae (Pl. 17, figs. 4, 11, 12). Rhabdosomes very

delicate in appearance. Mid-ventral lists of first pair of thecae well developed, remainder of thecae with mid-ventral lists exceedingly reduced to small fragments on thecal lips (Pl. 17, fig. 3, 6, 8, 11–13); thus genicular thecal lists do not have any connections with mid-ventral lists. (Pl. 17, fig. 3). Thecal lips usually thicker than other lists, thickening developed in horizontal plane (Pl. 17, fig. 3). Outer ancora occasionally developed as single lists (Pl. 17, figs. 2, 13), although usually not developed (Pl. 17, fig. 1). Appendix short (Pl. 17, figs. 7, 8), usually not preserved.

Remarks. *Neogothograptus melchini* is the most reduced form among the species of *Neogothograptus*. The lack of reticular lists and the strong reduction of the mid-ventral lists to small fragments results in the rhabdosome of *N. melchini* being very delicate. There is some parallelism in the reduction of the mid-ventral lists in *N. melchini* and the reduction of the lists seen in *Holoretolites atrabecularis* (see below for description).

Neogothograptus thorsteinssoni n. sp.

Pl. 7, figs. 1, 2, 5, 7, 8; Pl. 8, figs. 1–11;

Pl. 9, figs. 1–5; Pl. 10, figs. 1–7; Pl. 26, figs. 5, 6.

1994 *Holoretolites* (*Baculograptus*) *erraticus* (Eisenack), Lenz p. 858, 6.1–6.6, 6.9, 6.11.

Holotype. GSC 125981, TC 312B, northeastern Cornwallis Island, Pl. 9, fig. 3.

Etymology. In honor of R. Thorsteinsson who first discovered uncompressed graptolites in Arctic Canada.

Diagnosis. Reticulum of delicate lists and small meshes well developed on ancora sleeve, outer ancora, and thecal walls, as well as on proximo-ventral and lateral orifices in mature rhabdosomes. Appendix well developed.

Studied material. BH 57.6 m, 18 specimens; BH-82.5 m, 5 fragments; BH-2 92 m, 1 specimen; BH-2 118 m, 2 specimens; BH-2-135 m, 2 fragments; BH-2-137 m, 2 fragments; TC 711B, 5 mature rhabdosomes st. 215; several flattened specimens: SJF 145 m and HH 72 m, AB2-99, 25.5 m, several fragments; one fragment AB2-99, 31 m, 20 specimens GP 12 m, TC 312B.

Description. Mature specimens with 5 or 6 pairs of thecae and well-developed appendix. Thecal framework lists usually showing characteristic *Neogothograptus* pattern. Measurements similar to *Neogothograptus purus purus* (up to 7 mm long and about 0.9 mm across first thecal pair). Reticular lists are delicate, forming dense network on all walls of rhabdosome. Reticulum additionally covers lateral and ventral orifices in mature specimens (Pl. 8, figs. 9, 11; Pl. 9, figs. 1–3, 5). Outer ancora reticular lists completely cover ancora umbrella in mature specimens (Pl. 8, figs. 4, 8, 9, 11; Pl. 9, fig. 5; Pl. 10, fig. 2). Thecal lips thickened horizontally with paired labiate structures (Pl. 8, figs. 2, 4, 7), similar to *N. purus labiatus*. Appendix usually long, densely reticulated, tubular shape, rounded (Pl. 9, fig. 2; Pl. 10, figs. 4, 5). Some specimens develop unusually strong hoods on first thecae (Pl. 7, figs. 2, 5).

Remarks. *N. thorsteinssoni* n. sp. is one of the most densely reticulate forms in the genus, and among other Ludlow retio-

litids as well. The dense reticulation also covers the proximo-lateral and ventral orifices, a feature unique among retiolitids. Wide lips with characteristic paired labiate structures are seemingly typical for the Arctic Canadian forms, since they are prominently seen in *Neogothograptus purus labiatus* n. subsp. and, to a lesser extent, in *Neogothograptus alatifomis* n. sp. *N. thorsteinssoni* is very similar to *N. purus labiatus* in size, overall shape, and possession of thickened apertural lips. It differs in its a less, to much less, robust thecal framework along its lateral walls, and in possessing a dense and continuous reticulum at even early astogenetic stages.

Genus *Holoretiolites* Eisenack, 1951

Type species: Holoretiolites mancki (Münch, 1931), Baltic erratic boulder, Uckemark, Templin, Germany; Silurian.

Diagnosis. For emended diagnosis, see Kozłowska-Dawidziuk, 1995, p. 307.

Species included. *H. mancki* (Münch, 1931), *H. erraticus* Eisenack, 1951, *H. manckoides* Kozłowska-Dawidziuk, 1995; *H. atrabecularis* Kozłowska-Dawidziuk, 1995.

Holoretiolites manckoides Kozłowska-Dawidziuk, 1995
Pl. 18, figs. 1–8; Pl. 19, figs. 1–10

1995, *Holoretiolites manckoides* Kozłowska-Dawidziuk; p. 309, fig. 27B.

Type. Holotype ZPAL G. XVI/1347, *C. hemiavertus/avertus* Biozone, Mielnik borehole, depth 954.0–960 m, Poland.

Studied material. RC01-1, 22 m, one complete rhabdosome and four fragments; AB2-99, 58.5 m, one complete specimen and 18 fragments.

Description. Longest rhabdosome 5 mm long, contains six pairs of thecae (Pl. 18, fig. 5). Width of ancora umbrella 0.8 mm, the widest part is 1.5 mm at the level of third pair of thecae; rhabdosome narrowing slightly distally to about 1.25 mm. Thecal orifice shape regular rounded to rhomboidal (Pl. 19, figs. 3, 4, 7). Virgella usually preserved as short fragment connected to ancora (Pl. 18, figs. 2, 3; Pl. 19, figs. 1, 2, 8–10); the longest virgella fragment is 0.4 mm (Pl. 18, figs. 4, 5).

Remarks. *Holoretiolites manckoides* from Arctic Canada is similar to material from Poland (Kozłowska-Dawidziuk 1995), but attains a slightly greater maximum width. *H. manckoides* is the largest species of *Holoretiolites*.

Holoretiolites atrabecularis Kozłowska-Dawidziuk, 1995
Pl. 20, figs. 1–11

1995 *Holoretiolites atrabecularis* Kozłowska-Dawidziuk; p. 310, figs. 28A–C; 29.

Type. Holotype ZPAL G. XVI/1529, *L. parascanicus* Biozone, Mielnik borehole, depth 972.0 m, Poland.

Study material. RC01-1, 22 m, 20 fragments.

Description. There is no complete rhabdosome; fragments are either proximal end with ancora umbrella and first pair

of thecae, or several distal thecae without proximal end (Pl. 20). Maximum width 0.6–0.7 mm across ancora umbrella; i.e., identical to the type material from Poland. First thecal pair with mid-ventral lists, remainder of thecae with only fragments, rhabdosome without reticulum. Zigzag lists connecting thecal lists; thecal apertures ovate, lips much thicker than other lists. Some genicular thecal lists very thin (Pl. 20, fig. 9) or not developed in their medial distal regions (Pl. 20, figs. 8, 10). Virgella preserved only as small fragments (Pl. 20, figs. 1, 2, 5).

Remarks. Specimens of *H. atrabecularis* from Arctic Canada demonstrate a somewhat greater reduction of the genicular thecal lists (Pl. 20, figs. 4, 8, 10, 11), as compared with those in the Polish collections.

Genus *Spinograptus* Bouček and Münch, 1952

Type species. Retiolites spinosus Wood, 1900; pl. 25, fig. 29A, Builth District, UK, *nilssoni* Biozone.

Diagnosis. For emended diagnosis, see Kozłowska-Dawidziuk, 1995, p. 312.

Species included. *Spinograptus spinosus* (Wood, 1900), *S. munchi* (Eisenack, 1951), *S. clathrospinosus* (Eisenack, 1951), *S. lawsoni* (Holland, Rickards and Warren, 1969), *S. quadratus* (Lenz, 1993), *S. reticulolawsoni* Kozłowska-Dawidziuk, 1997, *S. latespinosus* Kozłowska-Dawidziuk, 1997, *S. praeobustus* Lenz and Kozłowska-Dawidziuk, 2002.

Spinograptus spinosus (Wood, 1900)
Pl. 21, figs. 1, 2, 4–6, 8, 10; Pl. 26, figs. 2, 10

1900 *Spinograptus spinosus* Wood; p. 485, pl. 25: figs. 29A, B, text-fig. 26B.

1983 *Spinograptus spinosus* (Wood); Obut and Zaslavskaya, pp. 111–112, pl. 27: 1–6.

1995 *Spinograptus spinosus* (Wood); Kozłowska-Dawidziuk, p. 313, fig. 15B.

1997 *Spinograptus spinosus* (Wood); Kozłowska-Dawidziuk, p. 405, figs. 13C, D.

Type. *Spinograptus spinosus* Wood, p. 485, pl. 25, figs. 29A, B, text-fig. 26B.

Studied material. Isolated: GP 12 m, 10 fragments; several flattened specimens from SJF 145 m and HH 72 m.

Discussion. The rhabdosomes are fragmentary with most genicular spines broken off, although those that are preserved show either no reticulofusellar structure or only that developed at the tip of the spine. In those spines in which the reticulofusellar structures are distally developed, they remain narrow. The density of the reticulum is greater in *S. spinosus* than in most other species of *Spinograptus*.

Spinograptus clathrospinosus (Eisenack, 1951)
Pl. 21, figs. 3, 7, 9; Pl. 26, fig. 1

1951 *Retiolites clathrospinosus* n. sp.; Eisenack; p. 139, pl. 23: 1, 2.

1978 *Spinograptus* cf. *spinosus* (Wood); Lenz; p. 636, pl. 7: 3, 4.

- 1993 *Agastograptus clathrospinosus* (Eisenack); Lenz: p. 15, pl. 3: 1, 2, 4, 7, pl. 4: 6, 8.
 1995 *Spinograptus clathrospinosus* (Eisenack); Kozłowska-Dawidziuk, p. 314, pl. 31B, pl. 32C.
 1995 *Agastograptus clathrospinosus* (Eisenack); Rickards, Packham, Wright and Williamson: p. 34: fig. 18D.
 1997 *Spinograptus clathrospinosus* (Eisenack); Kozłowska-Dawidziuk: p. 405, figs. 13A, B.
 1997 *Agastograptus clathrospinosus* (Eisenack); Zhang and Lenz: p. 1225, figs. 3G–J.
 2001 *Spinograptus clathrospinosus* (Eisenack); Kozłowska-Dawidziuk, Lenz, and Storch, p. 153, figs. 5.9, 5.13, 5.15, 7.6.
 2002 *Spinograptus clathrospinosus* (Eisenack); Lenz and Kozłowska-Dawidziuk, figs. 13.6–13.8, 14.7, 14.10, 16.13–16.15.

Type. *Retiolites clathrospinosus* Eisenack, 1951, 198 nr. 3, pl. 23, fig. 1, Baltic erratic boulder, Silurian.

Studied material. Isolated material: SJF 145 m, hundreds of fragments of specimens with genicular processes broken off; 155 m, 3 fragments of processes; AB-99, 52 m, few small fragments; several flattened specimens from HH 112.5 m.

Discussion. Rhabdosomes from the collection are mostly large fragments in which most genicular processes are broken off, making study of the nature of the processes difficult. The main difference between *S. spinosus* and *S. clathrospinosus* is in development of the genicular processes. The processes in *S. spinosus* are thin with reticulofusellar structures visible only on their distal tips (Pl. 21, fig. 8), whereas in *S. clathrospinosus* the entire genicular process is wider with well-developed reticulofusellar structures throughout its length (Pl. 21, fig. 7). A further difference is that the rhabdosome of *S. clathrospinosus* is consistently almost twice as wide as *S. spinosus*.

Spinograptus quadratus (Lenz, 1993)

Pl. 22, figs. 1–10

1993. *Agastograptus quadratus* Lenz: p. 16, pl. 5: 1–10.

Type. Holotype GSC 99173, SJF 155 m.

Studied material. SJF 155 m, st. 23; 26 fragments, in addition to those illustrated in Lenz 1993.

Description. Longest rhabdosome contains nine pairs of thecae. Rhabdosome thecal walls almost parallel to rhabdosomal axis (Pl. 22, fig. 5); rhabdosome width (measured between pleural lists) about 1 mm. Outer ancora is not present. Reticulum developed on ancora sleeve wall as large mesh network. Paired reticulofusellar genicular processes present, first appearing on medial thecae. Processes about 0.5 mm long and about half that in width; some developed close to mid-ventral list (Pl. 22, fig. 6), and occasionally some small processes may grow on mid-ventral list. Virgella usually preserved as a short list, occasionally longer (Pl. 22, fig. 5). Nema occasionally partially preserved (Pl. 22, figs. 5, 10).

Discussion. This species has been well illustrated and discussed in Lenz (1993, p. 16, pl. 5, figs. 1–10), and consequently, further discussion is unnecessary.

Genus *Plectograptus* Moberg and Törnquist, 1909

Type species. *Retiolites macilentus* Törnquist, 1887, from Wetterahammer area (Colonusskiffern), Thüringia, Ludlow.

Diagnosis. For an extensive emended diagnosis, see Kozłowska-Dawidziuk, 2002.

Species included. *Plectograptus macilentus* (Törnquist 1887), *P. robustus* (Obut and Zaslavskaya 1983), *P. wimani* (Eisenack 1951).

Plectograptus macilentus (Törnquist, 1887)

Pl. 23, figs. 1–5; Pl. 24, figs. 4–6, 8–12;

Pl. 26, fig. 15

1887 *Retiolites macilentus* n. sp.; Törnquist, p. 491, fig. 3.

1909 *Plectograptus macilentus* (Törnquist); Moberg and Törnquist, p. 13, pl. 1, figs. 1–12.

1951 *Plectograptus tetracanthus* n. sp.; Eisenack, p. 140, pl. 23, figs. 6–8; pl. 25, fig. 9, text-figs. 4, 5.

1952 *Plectograptus macilentus* (Törnquist); Bouček and Münch, p. 120, figs. 7a–f, pl. 1: 1–4.

1993a *Plectograptus* (*Plectograptus*) *macilentus* (Törnquist); Lenz, p. 13–14, pl. 1: 6–8.

1995 *Plectograptus macilentus* (Törnquist); Kozłowska-Dawidziuk, p. 317, fig. 33.

Type. Lund University type numbers 0667–0669, illustrated on p. 491, fig. 3, from Wetterahammer area, Thüringia.

Studied material. Isolated: BH1-91, 57.6 m (st. 171, st. 114); MCM-91, 14 fragments; BH-2, 146.5 m, 3 fragments; several flattened specimens from TC #2; and SB 97 A 16 m.

Description. Most of the collections represent fragments of rhabdosomes. One long specimen with broken proximal end and with nine pairs of thecae is 9.5 mm long (Pl. 23, fig. 4); width of more or less parallel-sided ancora sleeve wall about 1.5 mm. Best preserved proximal end of young rhabdosome with three parallel-sided thecae (Pl. 24, figs. 4–6, 8–12). Ancora umbrella simple, with one pair of reduced lists (Pl. 23, figs. 1, 5). Zigzag lists very regular, forming hexagonal or rhomboidal structure with pleural lists. Virgella usually preserved as short fragment. In isolated material nema preserved in only one young rhabdosome (Pl. 23, fig. 5). Mid-ventral lists are usually broken off but clearly were present throughout (Pl. 23, figs. 2, 4).

Discussion. In spite of the fragmentary nature of the collection, the ultrastructural characters on isolated specimens are very well preserved and clearly show list seams occurring on the inside (Pl. 24, figs. 4–6, 8–12). Generally speaking, however, characteristics of the species include the open and very orderly thecal framework with prominently zigzag lists, unornamented thecal walls, and presence throughout of thecal mid-ventral processes. These are often broken or incomplete in some specimens. Nevertheless, more detailed study is required to understand the fundamental morphology of the genus.

Plectograptus robustus (Obut and Zaslavskaya, 1983)
Pl. 24, figs. 1–3, 7; Pl. 26, figs. 3, 4, 8, 9, 11–14

1983 *Agastograptus robustus* n. sp.; Obut and Zaslavskaya, p. 108, pl. 24, figs. 1–3.

1986 *Agastograptus robustus* Obut and Zaslavskaya; Obut and Zaslavskaya, p. 210, figs. a–c.

2002 *Plectograptus robustus* (Obut and Zaslavskaya), Kozłowska-Dawidziuk, p. 462, figs. 2C, D.

Type. Institute of Geology and Geophysics, Novosibirsk specimen nr 25142-4, pl. 1, fig. 1, North Kaliningrad R-1 borehole, *milsoni* Biozone.

Studied material. Several isolated fragments of rhabdosomes from BH-91, 57.6 m (st. 171); several flattened specimens from each of HH 55.5 m; BH2 235 m, CP 1470 (480.1 m); and BH2 135 m.

Description. The largest fragment comprises a proximal end with three thecae preserved on the th 1¹ side (Pl. 24, fig. 7). Mid-ventral lists are well developed. Robust paired thecal genicular processes well developed on margins of genicular lists. Processes well preserved on flattened specimens (Pl. 26, figs. 9, 14), although largest flattened specimen (Pl. 26, fig. 12) does not clearly show the nature of processes.

Discussion. Prior to this study, *P. robustus* was known only from Kaliningrad (Obut and Zaslavskaya, 1983) and from

northeastern Poland (Kozłowska-Dawidziuk 2002), both part of the East European Platform. This species may be looked upon as an otherwise typical *P. macilentus*, to which has been added prominent and fairly complex paired genicular spines. In the absence of the processes, the two species would be difficult, if not impossible, to distinguish.

Plectograptus? sp.

Pl. 25, figs. 1–8

Studied material. BH 92 m several small fragments; BH-2 140 m one fragment; BH-2 145 m one fragment.

Description. Several fragments represented only by parts of thecal walls (Pl. 25, figs. 1, 2), and ancora sleeve. Well-developed, paired genicular processes may be present (Pl. 25, figs. 5, 8), along with short mid-ventral lists and part of ancora sleeve wall. Ancora sleeve list pattern shows hexagonal meshes with some reticulum (Pl. 25, figs. 3, 4, 7). Some lists with seams developed on outside of ancora sleeve wall (Pl. 25, figs. 3, 6, 7).

Discussion. The pattern of lists forming the ancora sleeve is similar to that typical of *Plectograptus*. The lists with seams growing on the outside of the ancora sleeve are similar to those observed in *Cometograptus* Kozłowska-Dawidziuk, from the *lundgreni* Biozone. The lack of any proximal end prevents confident assignment even at the genus level.

Family MONOGRAPTIDAE Lapworth, 1873

Genus *Pristiograptus* Jaekel, 1889

Type species. *Graptolithus dubius* Suess, 1851, p. 115, pl. 9, figs. 5a, b. From the middle Wenlock of the Barrandian region, Czech Republic.

Diagnosis. Thecae straight, cylindrical, with ventral wall nearly or quite straight. Aperture without any supplementary structures. (After Urbanek, 1958, p. 12)

Pristiograptus dubius (Suess, 1851)

Pl. 29, figs. 9, 11, 18, 19, 27; Pl. 41, figs. 1, 2;
Pl. 46, figs. 1, 2

1851 *Graptolithus dubius* Suess; p. 115, pl. 9, figs. 5a, b.

1936 *Monograptus dubius ludlowensis* Bouček; p. 139, pl. 1, figs. 8–10.

1953 *Monograptus dubius* (Suess); Walker, p. 365, figs. 2, 3.

1955 *Monograptus dubius* (Suess); Kühne, p. 360, figs. 2A–K.

1958 *Pristiograptus dubius* (Suess); Urbanek, p. 83, text-fig. 57; pl. 5, fig. 1, 2; text-pl. 7.

1959 *Monograptus dubius thuringicus* Jaeger; p. 127, pl. 11, figs. 3–7.

Type. *Graptolithus dubius* Suess, 1851, p. 115, pl. 9, figs. 5a, b. From the middle Wenlock of the Barrandian region, Czech Republic.

Study material. A few flattened specimens from GP (16, 18, 20 m); HH-93? m. Numerous isolated specimens from SB 97A, 1.5 m, SB D, 75 m, and BH2-98, 146.5 m and 206 m.

Discussion. The morphology of this species is simple: a straight sicula 2.0–2.5 mm long, with a straight to slightly ventrally curved dorsal wall, a proximally projecting virgella, tube-like thecae inclined 20°–30° and overlapping one-half to two-thirds, and in which, typically, the apertural rim of theca 1 and sometimes several other proximal thecae form an obtuse angle with the thecal axis, whereas in the remainder, they are at right angles. The thecal rims are characteristically somewhat thickened. Rhabdosomal maximum width ranges up to at least 1.7 mm.

The relationship to *P. jaegeri* (Holland, Rickards, and Warren 1969) is close; *P. jaegeri* typically possesses a completely and rigidly straight sicula dorsal wall, often the development of very weak lappets on theca 1, more pronounced and more obviously thickened intertheal septa (see Lenz and Kozłowska-Dawidziuk 1998), and a somewhat more rapid distal widening of the rhabdosome.

Rickards and Wright (2003) have recently made a study of the *Pristiograptus dubius* group and its iterative evolution. They more or less formally recognize 13 species and subspecies of so-called broad and narrow forms of *Pristiograptus dubius*-related forms, albeit on, sometimes, rather subtle differences. They recognize, however, that known biostratigraphic position has, in the past, often had a strong influence on species identification. We prefer, therefore, to

take a more conservative approach, and simply assign all of our material to *Pristiograptus dubius* (s.l.).

Pristiograptus fragmentalis (Bouček, 1936)

Pl. 34, figs. 1–7

1936 *Monograptus fragmentalis* Bouček: p. 143, text-fig. 11-n.

1986 *Monograptus fragmentalis* Bouček: Jaeger, p. 316, pl. 2, figs. 14, 15, 18, 20, 21.

1990 "*Pristiograptus*" sp. A, Lenz, figs. 4C–E.

1997a *Pristiograptus dubius fragmentalis* (Bouček): Urbanek, p. 159, pl. 15, figs. 5, 6.

Type. The types are illustrated in Bouček 1936, Fig. 1, figs. 1–n, of which fig. 1 is the holotype; from the Upper Ludlow of the Lochkov area, Czech Republic.

Study material. Very common with dozens of specimens, both flattened and isolated. Flattened material from AB2-99 (81, 90, 106 m); SJF (191, 221.5 m); GP (41, 51, 52.5 m); HH (55.5 m); SB D (75, 325 m); TC (#3A, #3B, #4, #5?, #6, #8); TWW (22.5?, 23.8, 25 m); and isolated material from AB2-99 (58.5?, 94 m); BH2, 92 m; SB 97A, 14 m; and RC01-1 (17.5 m). Ranges from lower to upper Ludlow, but is much more common in the middle and upper Ludlow.

Description. Rhabdosome robust, typically straight throughout except for weak ventral curvature in the sicular region. Sicula 2.1–2.5 mm long, apex almost level with theca 3 aperture, virgella projecting proximally. Thecae tube-like, inclined 30°–40°, thickened thecal rims about at right angle to thecal axis. Ventral walls of thecae generally weakly geniculated. Theca 1 often with weak to moderately developed lappets. Thecae spaced at 5.0–5.5 in 5 mm proximally and about 4 in 5 mm distally. Rhabdosome width 0.7–1.1 mm across theca 1 (uncompressed specimens), increasing slowly to distal maximum of almost 3 mm (flattened material).

Discussion. Jaeger (1986, p. 316) aptly commented, "This species can be characterized as a giant *M. dubius*". Little more needs to be said, since it differs from *P. dubius* only in being larger, wider, and more robust, particularly evident in the proximal region, in possessing a somewhat longer sicula on average and, generally, having weak lappet development on the first theca (Pl. 34, fig. 1). It differs from *P. dubius labiatus* Urbanek 1997 in lacking thecae with excessively thickened and unduose apertural lips, and from *P. pseudolatus* Rickards 1965 in showing a higher thecal inclination and a considerably longer sicula.

Genus *Pseudomonoclimacis* Mikhailova, 1975

Type species. *Pseudomonoclimacis elegans* Mikhailova, 1975, p. 156, figs. 3–5; pl. 3, figs. 2, 3. From the Pridoli of Kazakhstan.

Diagnosis. Monograptid typically with ventrally curved sicula often with dorsal tongue, and monoclimacid thecal profile. The almost right angle junction between prothecal and metathecal interthecal septa is prominently visible due to thickening.

Remarks. The genus *Pseudomonoclimacis*, a Ludlow taxon, and almost certainly a derivative of the *dubius* group, differs from *P. dubius* in only a few, rather subtle ways; chiefly, in possessing a generally more curved and slightly more complex sicula, often with well-developed dorsal sicular process, moderately to strongly geniculated thecae, and an abrupt and strong, almost right angle juncture between the prothecal and metathecal septa, made clearly visible by its possession of well-developed, continuous and arcuate thickened interthecal septa (see Lenz and Kozłowska-Dawidziuk 1998, Pl. 1, figs. 4, 5, 10 for examples of thickened interthecal septa) that make almost right-angle contacts with the external trace of the metathecal septa and which are typical of the genus (Mihajlović 1975). Furthermore, the thecal apertures of most species are more complex than those seen in the *Pristiograptus dubius* group. These differences, although somewhat subtle, are stratigraphically consistent and readily recognizable, and use of the genus is fully justified (e.g., Koren' 1986; Urbanek 1997a).

Pseudomonoclimacis hispinosus Lenz, 1988

Pl. 29, figs. 15–17

1988 *Pseudomonoclimacis?* *hispinosus* Lenz: p. 360, figs. 2J–N.

Types. Holotype GSC 86140, and paratypes 86141–86144, from the Ludlow of Tetlit Creek, Yukon.

Study material. Only four or five isolated specimens from SB2-99 (7 m, 44 m?), and, tentatively, a few flattened specimens from TC #4.

Discussion. This species was originally described from northern Yukon (Lenz 1988), but only in flattened form. It is characterized by possessing simple, but strongly geniculated thecae that overlap only by about 50%, and two, long, opposing virgellar and dorsal sicular spines. In the latter feature, it is identical to *Monograptus ceratus* Lenz, 1988, but differs in completely lacking thecal or genicular hoods and possessing thecal apertural rims that are more or less perpendicular to long axis of the rhabdosome. Furthermore, a thecal hood is always present on the second and subsequent thecae, and is often found on the first theca of *Monograptus ceratus*.

Pseudomonoclimacis? brevicucullus n. sp.

Pl. 29, figs. 13, 14, 20–26

Material and type. Dozens of fragments from RC01, #1–22 m, and five fragmentary, isolated specimens, all from AB2-99, 58.5 m, holotype GSC 126108, Pl. 29, fig. 20.

Etymology. From Latin, *brevis*, for short, and *cucullus*, for cap or hood, referring to the very short, thecal hoods or genicular processes.

Diagnosis. Proximal three to eight thecae simple, ventral wall slightly geniculated, without genicular hoods, more distal thecae with short but strong genicular hoods.

Description. Rhabdosome more or less straight, with a weak ventral curvature in the sicular region, and weak dorsal curvature about level of thecae 2 or 3, and distal regions

straight. Proximal region delicate in appearance, very gradually becoming more robust distally. Sicula 2.0–2.2 mm long, apex level with mid-region of theca 2, with normal, proximally projecting virgella and generally possessing a moderate- to well-developed dorsal wall genicular hood. Ventral walls of thecae 1–8 weakly to moderately geniculated, apertural rims more or less perpendicular to rhabdosome axis, and thecal rims thickened. Distal thecae strongly geniculated, with short, but robust and broad genicular hoods that project ventrally about 0.16–0.2 mm and, to a limited extent, progressively increase in length and strength distally. Thecae overlapping only one-fifth to one-quarter proximally, increasing gradually to one-half distally. Width across theca 1 in uncompressed specimens about 0.45–0.6 mm. Rhabdosome widening slowly distally to at least 1.5–1.6 mm exclusive of genicular hoods (uncompressed material). Thecae spaced about 5.5 in 5 mm proximally and distally.

Discussion. This species is, morphologically, very similar to early growth stages of *Pseudomonoclimacis hispinosus* but totally lacks the paired, divergent virgellar and antivirgellar spines. In like manner, the early growth stages of *Pseudomonoclimacis? brevicucullus* n. sp. and *Pseudomonoclimacis dalejensis rectus* n. subsp., are virtually indistinguishable, whereas their distal regions are readily distinguished by the presence and absence, respectively, of genicular hoods. Some specimens from section RC1-01 with proximal ends that are only about one-half to two-thirds the width of the more abundant material (see Pl. 29, figs. 13, 14, 26) are, with some hesitation, assigned to this species.

Pseudomonoclimacis dalejensis dalejensis (Bouček, 1936)
Pl. 33, figs. 4–8, 11–16, 18–29

- 1936 *Monograptus dalejensis* Bouček; p. 146, figs. 2f–i.
1955 *Monograptus haupti* Kühne, p. 365, figs. 3A, B, D–F.
1958 *Monoclimacis haupti* (Kühne); Urbanek, p. 88, text-figs. 59–64; non pl. 5, fig. 5.
?1979 *Monoclimacis tauragensis* (Paškevičius); Paškevičius, p. 158, pl. 9, figs. 8, 9; pl. 24, figs. 11–15.
1986 *Monograptus dalejensis* Bouček; Jaeger, pl. 2, figs. 1, 2.
1988 *Pseudomonoclimacis tetlitensis* Lenz; p. 359, pl. 1, figs. 1, J; figs. 2E–I.
1990 *Pseudomonoclimacis dalejensis* (Bouček); Lenz, figs. 3V–Y, AA.
1990 *Pseudomonoclimacis tetlitensis* Lenz; Lenz, figs. 3K–M.
1992 *Pseudomonoclimacis dalejensis* (Bouček); Lenz, p. 206, pl. 3, figs. A–G.
1995 *Monograptus dalejensis dalejensis* Bouček; Rickards, Packham, Wright and Williamson, p. 46, figs. 25D, 26A–E.
1995 *Monograptus dalejensis* Bouček; Štorch, p. 69, pl. 5, fig. 6; pl. 6, fig. 4; text-figs. 8D–I.
1999 *Monograptus? haupti* Kühne; Maletz, p. 287, figs. 3A–F.

Types. The types are illustrated in Bouček's (1936) Fig. 2, figs. f–i, of which fig. g is the holotype, a specimen that appears to be somewhat distorted. From the middle Ludlow of the Řeporyje area, Barrandian region, Czech Republic.

Study material. Very common and abundant in flattened as well as isolated material. Flattened material: AB2-99 (81, 116 m); SJF (174?, 191, 195?, 211, 221.5?, 284? m); GP (36.5?, 38, 41, 52.5 m); HH (93?, 195 m?); SB-D (300, 320 m); TC (#6, #8, #12); TWN (4.5, 7 m); Isolated material from SB97-A 14, 16 m; SBC88 (#4 @ 15 m, #8H); SB90-B (5, 27 m); SB90-D (10, 75 m); AB2-99 (58.5, 63, 82 m); BH (57.6?, 86 m); BH 2 (153, 198, 206, 365, 389 m); RC1-01, 17.5, 20, 21, 22 m. Rare in the lower Ludlow, but common to abundant in the mid- and upper Ludlow.

Description. Rhabdosome showing tremendous variation, ranging from rather delicate to robust, and the collections are arbitrarily divided into two major morphotype groups: delicate and robust. Sicular region weakly to very strongly ventrally curved, weakly dorsally curved in region of thecae 2–3 and straight thereafter. Sicula weakly to strongly ventrally curved, from as little as 5°–10° in "delicate" specimens, and up to 45° in the "robust" material, 2.0–2.5 mm long, apex reaching level of aperture or mid-region of theca 2. Rhabdosome 0.5–1.0 mm wide across theca 1, the width ranging from lesser width in the "delicate" forms, and greater in the "robust" specimens (isolated material), at least 1.1 mm across theca 5, and about 1.6 mm (flattened material) distally. Thecae moderately to strongly geniculated throughout, but more strongly geniculated in robust forms, thecal aperture rims about perpendicular to rhabdosome axis, rims thickened. Intertheal septa generally strongly developed.

Discussion. This is an extremely variable and troublesome species. At one end of the morphological variation are relatively delicate and gradually widening rhabdosomes with only weak moderate curvature of the sicular region and moderately geniculated thecae (Pl. 33, figs. 5, 6, 11), while at the other are rapidly widening robust forms with strongly curved siculae and sicular regions, and more geniculated thecae (pl. 33, figs. 20, 21, 24–29). End members thus could well be considered as separate species. However, a complete gradation is seen, sometimes in the same collection. Measurements of proximal end curvature and "robustness" vs. stratigraphic position were made to test whether this range of variation might reflect an evolutionary development. However, while there appears to be some very weak tendency towards the presence of more robust and more curved forms higher up the stratigraphic column, there are many exceptions, and the suggested trends are considered to be statistically meaningless. All forms are thus considered eco-phenotypic variations of a single species.

Pseudomonoclimacis dalejensis dalejensis would appear to have been a eurytopic species in that it ranges through a considerable stratigraphic/biostratigraphic interval and occurs in a variety of lithologies. In Arctic Canada and northern Yukon, for example, the subspecies is common through the entire middle and upper Ludlow, whereas in Yunnan, south China, it ranges through at least the upper part of the lower Ludlow, as well as the middle Ludlow (Zhang and Lenz 1997). Its total stratigraphic/biostratigraphic range elsewhere is unknown. Although the occurrence of the subspecies is typically within the middle and upper Ludlow, its first occurrence in the Arctic is very occasionally as low as the

progenitor Biozone, making this the earliest known occurrence anywhere.

Pseudomonoclimacis dalejensis rectus n. subsp.

Pl. 33, figs. 1–3, 9, 10, 17; Pl. 41, figs. 3, 15

Material and types. Fifteen isolated specimens from SB 97, A1.5 m, and eight specimens from SB-D #1; and several flattened specimens from AB4-99, 116 m. Holotype GSC 126167 from SB 97, A1.5 m, pl. 33, fig. 2.

Etymology. From Latin *rectus*, for straight, referring to the straight, non-curved proximal dorsal region.

Diagnosis. Rhabdosome straight, widening gradually but considerably, with delicate proximal end, sicula essentially straight, thecae weakly to moderately geniculated throughout. Differs from the typical form in possessing a straight rhabdosome and sicula.

Description. Rhabdosome essentially straight, but some specimens with very weak dorsal curvature in region of thecae 2–6 (pl. 33, figs. 3, 15). Sicula cone shaped, with dorsal wall straight to very gently curved in a ventral direction, 1.3–1.7 mm long, apex at level of mid- to apertural region of theca 2. Thecae inclined about 15° proximally to about 30° distally, overlapping one-quarter to one-third proximally to one-half distally, ventral walls weakly to moderately geniculated, apertural margins almost perpendicular to rhabdosome axis, all thecal rims distinctly thickened. Thecae 5–6 in 5 mm proximally and about 4.5–5 in 5 mm distally. Intertheal septa strong and well developed. Rhabdosome 0.5–0.6 mm across theca 1, 0.7–0.75 mm across theca 5, increasing slowly to about 1.5 mm distally (specimens in full relief).

Discussion. This form might well be considered the simplest and least extreme variant of *Pseudomonoclimacis dalejensis* and, at first, was considered to be just that. However, the fact that the form can consistently be recognized in both flattened and isolated form justifies the erection of a separate subspecies. In particular, the relatively straight sicula, low inclination of the thecae, relatively delicate rhabdosome, and weak, to no, dorsal curvature of the proximal end seem to be stable diagnostic features.

Genus *Monograptus* Geinitz, 1852

Type species. *Lomatoceras priodon* Bronn, 1835, p. 55, pl. I, fig. 13. From the Silurian of Germany.

Diagnosis. Monograptid in which thecae sigmoidally curved, free metathecal portion strongly curved towards proximal region, apertures directed proximally or ventro-proximally. Thecae of some species with lateral spines near aperture.

Remarks. *Monograptus* (s.s.), that is, monograptids with metathecae comparable to those in *M. priodon*, reappears abruptly, in the form of species such as *M. uncinatus* Tullberg, 1883, and *M. micropoma* (Jaekel, 1889), at or near the base of the Ludlow, following a hiatus through all or most of the Upper Homerian. Beginning in about the mid-Ludlow, however, the genus underwent modest periodic proliferation, and continued so until its demise in the latest Early Devo-

nian, Emsian. Whether *Monograptus* appeared *de novo* from some *dubius* derivative near the base of the Ludlow, or whether it was a "Lazarus taxon" (see Urbanek 1993) that abruptly expanded into global habitats outside some presently unknown refugium, is debatable. Although the latter explanation is preferred, no strong independent evidence exists.

Monograptus cf. *beatus* Koren', 1983

Not illustrated (see Lenz 1990)

cf. 1983 *Monograptus beatus* Koren'; p. 416, pl. 49, figs. 7–10; pl. 50, figs. 1–5; text-figs. 4b–g.

cf. 1986 *Monograptus beatus* Koren'; Koren', p. 91, pl. 18, figs. 4–6; figs. 12a–i.

1990 *Monograptus* cf. *beatus* Koren'; Lenz, figs. 4T, U.

cf. 1998 *Monograptus beatus* Koren'; Ni, Lenz and Chen, figs. 3K, 6B, G.

Type. CGM 12/10876; pl. 49, fig. 7, text-fig. 4b, from the *bouceki* Biozone of Kazakhstan.

Study material. Two flattened specimens only moderately preserved; tentatively identified from TC 88, 195 m. Previously figured in Lenz (1990).

Discussion. *Monograptus beatus* was tentatively identified on the strength of two specimens from the Arctic (Lenz 1990), only one of which preserved the proximal end of the rhabdosome. Like the Kazakhstan species, the Arctic specimens possess a straight, rather delicate rhabdosome and almost lobate thecae that do not overlap internally. However, the Arctic material is thinner and more delicate in appearance, metathecae are somewhat less lobate than characteristic, the intertheal septa are inclined at a somewhat higher angle to the rhabdosomal axis, and its sicula (seen only in one specimen) is apparently more or less straight rather than curved. A further difference is that the Arctic material occurs in the Upper Ludlow whereas that from Kazakhstan is present in about the middle Pridoli.

Monograptus bessobaensis Koren', 1986

Pl. 38, figs. 3–7; Pl. 45, figs. 13–16

?1972 *Monograptus* cf. *balticus* Teller; Jackson and Lenz, p. 585, figs. 21–K.

1986 *Monograptus bessobaensis* Koren'; p. 93, pl. 18, figs. 7–9; pl. 19, figs. 1–11; pl. 20, figs. 1, 13, 14.

Type. Figured in Koren' 1986, Pl. 18, fig. 7, text-fig. 13d, from the *formosus-bessobaensis* Biozone (Upper Ludlow) of the Tokrau sequence of Kazakhstan.

Study material. A few flattened specimens from each of TC #17, TWN 35 m (talus collection), and tentatively GP 57.5 m. From the upper Ludlow and lower Pridoli.

Description. Rhabdosome dorsal wall moderately to strongly dorsally curved between about the level of thecae 1 and 2, less so at level of thecae 3–4, weakly ventrally curved between levels of thecae 4–6, and straight thereafter. Width ranges from 0.7–0.8 mm across theca 1, and increases slowly to a distal maximum of about 1.3–1.4 mm, inclusive of thecal hoods. Sicula ventrally curved, curvature further

exaggerated by curvature of dorsal wall, 1.3–1.5 mm long. Thecae of *uncinatus* type but more claw-like in profile, with strongly and ventrally projecting metathecal hoods, the length and strength of which remain more or less constant throughout the length of rhabdosome, thecal apertures moderately deep; intertheal septa sigmoidally curved, not overlapping. Thecae number 6.5–7 in 5 mm proximally and about 5.5 in 5 mm distally.

Discussion. This species bears some resemblance to *M. beatus* from which it differs in possessing normal *uncinatus* type thecae, rather than lobate metathecal hoods; from *M. hamulosus* (Tsegelnyuk 1976), it differs in a proximal ventral curvature, and in widening more rapidly; from *M. valleculeus* (Tsegelnyuk 1976) it differs in its less robust rhabdosome and somewhat less ventrally projecting thecal hoods; and from *M. canaliculata* (Tsegelnyuk 1976) it differs in possessing a moderately ventrally curved rather than a straight proximal region, and in being much less robust. The form identified as *Monograptus* cf. *balticus* by Jackson and Lenz (1972) is most probably assignable to *Monograptus bessobaensis*, although in northern Yukon it occurs below the lowest occurrence of *Formosograptus formosus*; that is, slightly older than typical for the species.

Monograptus birchensis Berry and Murphy, 1975

Pl. 28, figs. 11–15; Pl. 39, figs. 1–8;

Pl. 45, figs. 11, 12, 24–26

1975 *Monograptus birchensis* Berry and Murphy; p. 48, pl. 1, figs. 1–4, 6, 7.

1990 *Monograptus* cf. *birchensis* Berry and Murphy; Lenz, figs. 4M–O.

Type. University of California, Riverside, type UCR 6140/1 (Pl. 1, fig. 1) from the Lower Devonian of Birch Creek, Nevada.

Study material. Very common and generally forming monospecific assemblages in uppermost Silurian or lowest Devonian strata. Flattened material from SJF (599 m), SJF 2; GP (130, 132 m); HH (198?, 204?, 210?, 219 m); SF (369, 394, 400, 410, 414, 428?, 448, 465, 474, 475 m); TC (#35, #36, #37); localities C198740, C1987421, C146446. Eight isolated specimens from C11445, Baillie Hamilton Island. Several topotype specimens collected from Birch Creek, Nevada, were available for comparative study.

Description. Rhabdosome robust, long; weakly dorsally curved through levels of thecae 1–5, very weakly ventrally curved through levels of thecae 4–7, and straight thereafter. Width across theca 1 is 1.0–1.1 mm, 1.2–1.5 mm at theca 5, and 1.9–2.2 mm distally (across thecal hoods). Sicula more or less cone-shaped, sometimes with moderately flaring and trumpet-like aperture, dorsal wall straight to slightly dorsally curved. Sicula 1.8–2.3 mm long, apex ranging from level with hood of theca 2 to about level with theca 3, aperture 0.4–1.0 mm wide, depending on the amount of flare; some specimens with proximally or proximo-ventrally projecting, slightly to fairly strongly ventrally curved, lip-like dorsal process in most specimens. Thecae of *uncinatus* type, with strong and well-developed thecal hoods that gradually, but

only slightly, lessen in strength and length distally. Theca 1 more strongly proximally curved than others; lateral width of thecal hoods in isolated specimens generally greater than width of prothecae. Thecae spaced 6–6.5 in 5 mm proximally, and 4.5–5 in 5 mm distally.

Discussion. The Arctic material was compared with several topotype specimens from Birch Canyon, Nevada (see pl. 45, fig. 26), and was found to compare favourably in all characteristics, with the exception of possessing a wider and sometimes more flared sicula aperture in some of the Arctic specimens. Of interest is the lip-like sicula dorsal process, also noted by Berry and Murphy (1975), a morphological feature more typical of Devonian monograptids (Jaeger 1970). In *M. birchensis*, the process is relatively short, but in some specimens is moderately to strongly ventrally curved.

As noted earlier, this species, while ranging through a considerable thickness of strata, generally occurs in monospecific assemblages, and as a result, no independent assessment of its age range is possible, except in the Twilight Creek section where several occurrences of *M. birchensis* are separated by a considerable thickness from the earliest Devonian index, *M. uniformis* Přibyl, 1940. On Eidsbotn River, Devon Island, it occurs with *Monograptus microdon curvatus* n. subsp., but the age range of that taxon too is in doubt. In Nevada, however, *M. birchensis* co-occurs only with the lowermost Devonian index species *M. uniformis*.

Monograptus bouceki Přibyl, 1940

Pl. 38, fig. 1; Pl. 45, figs. 5, 6?

1940 *Monograptus* (*Pomatograptus*) *bouceki* Přibyl; p. 71, pl. 1, fig. 7, 8; text-fig. 1.

1964 *Monograptus bouceki* Přibyl; Teller, p. 56, pl. 2, fig. 13; pl. 5, fig. 5; pl. 6, figs. 1–3; pl. 8, fig. 12, 13; pl. 14, figs. 4, 5.

1972 *Monograptus bouceki* Přibyl; Jackson and Lenz, p. 588, text-figs. 3A–F, I.

1975 *Monograptus bouceki* Přibyl; Lenz, p. 82, pl. 1, figs. 7, 10, 12–14; text-figs. 2A, C–F.

1981 *Monograptus bouceki* Přibyl; Přibyl, pl. 2, figs. 3–5.

1986 *Monograptus bouceki* Přibyl; Jaeger, p. 331, pl. 3, figs. 3, 7–11, 13, 15.

1986 *Monograptus bouceki* Přibyl; Koren, p. 95, pl. 20 figs. 2–4; fig. 15.

1990 *Monograptus bouceki* Přibyl; Lenz, fig. 4S.

1997 *Monograptus bouceki* Přibyl; Piçarra, Gutiérrez-Marco, Lenz, and Robardet, figs. 6B, G, H.

Types. Illustrated in Přibyl 1940, pl. 1, figs. 7, 8; text-fig. 1, from the Pridoli of the Barrandian region, Czech Republic.

Study material. Rare and only in flattened material from SF 100 m, and possibly TC #21.

Description. Rhabdosome at least 15 mm long, markedly and quite abruptly dorsally curved and relatively delicate in the interval of thecae 1–2, and straight and widening very rapidly thereafter. Sicula distinctly ventrally curved, 2.1 mm long in the single measurable specimen; apertural region tilted ventrally, virgella moderately long. Width at theca 1

about 1.05 mm, 1.5 mm across theca 5, and maximum distal width 1.9 mm (in single well-preserved specimen). Thecae of *uncinatus* type, but with long and prominent, claw-like thecal hoods proximally, slightly and progressively shorter and weaker distally, spaced about 6 in 5 mm proximally and 5.5 in 5 mm distally. Free portion of thecal hoods occupying almost one-half rhabdosome width. Intertheal septa not overlapping.

Discussion. Distinctive of the species are the rather abrupt dorsal curvature of the proximal end coupled with the relatively delicate appearance of the sicula end and the subsequent rapid widening, and the possession of long, claw-like thecal hoods. The Arctic material, although rare, matches the characteristics of the material described by Jaeger (1986) and Koren' (1986) very well. It differs somewhat from the more abundant Yukon material described in Jackson and Lenz (1972) only in being somewhat broader, but is otherwise similar in all other morphological characteristics.

Monograptus ceratus Lenz, 1988

Pl. 29, figs. 1–8, 10; Pl. 38, figs. 8–10, 16–19;

Pl. 45, figs. 1–4

1984 *Monograptus uncinatus* Tullberg?; Lenz, p. 971, fig. 1f.

1988 *Monograptus ceratus* Lenz, p. 362, figs. 3G–I.

1992 *Monograptus ceratus* Lenz; Lenz, p. 201, pl. 2, figs. H–K.

Types. Holotype GSC 86158, and paratypes GSC 86159 and 86160, from the middle Ludlow of Tetlit Creek, Yukon.

Study material. Fairly common; flattened material from SJF (180, 191, 195, 211 m); GP 36.5 m; SB-D, 300 m; SBC #6, #7C; TC #5; TWW (47.5, 52 m); TWN (0, 1.5 m); isolated material from SBC-88, 7A; AB2-99, 63 m?

Discussion. This species was first described from northern Yukon (Lenz 1988) and was subsequently recovered in un-compressed form from the Arctic (Lenz 1992). Thus far, the species appears to be endemic to northern and Arctic Canada. It is characterized by the possession of a long, dorsally projecting dorsal sicula spine, and an equally long ventrally or ventro-proximally projecting virgellar spine, and *uncinatus* type thecal hoods. Unlike most species of *Monograptus*, however, the first two to three thecae possess weak thecal hoods while distal hoods are prominent and become increasingly strong distally. Distal fragments of this species and *M. uncinatus* would probably be impossible to distinguish.

Only one other species, *Pseudomonoclimacis hispinosus*, possesses equally long and splayed out sicula spines, but that species is totally devoid of thecal hoods. Another species, *Pseudomonoclimacis brevicucullus* sp. nov. is somewhat similar in possessing proximally weak or no thecal hoods, and increasingly stronger distal thecal hoods. Unlike *M. ceratus*, however, its first two to three thecae are totally without thecal hoods, and it appears to lack the long, divergent proximal spines one of which is the virgella, although material with complete and well-preserved siculae is not available.

Monograptus microdon curvatus n. subsp.

Pl. 39, figs. 9–12; Pl. 45, figs. 18, 21–23

Type. Five flattened specimens, all from locality C146446, Eidsbotn, Devon Island. Holotype GSC 126286, pl. 39, fig. 11; pl. 45, fig. 22.

Study material. Eight flattened, poorly preserved specimens from locality C146446, Eidsbotn River. Found only in association with *Monograptus birchensis*.

Etymology. From Latin *curvus*, curve, for the strongly curved proximal end of the rhabdosome.

Diagnosis. Rhabdosome with typically small and strongly curved thecal hoods typical of the *microdon* group, but with a strongly dorsally curved proximal region.

Description. Rhabdosome more or less J-shaped; proximal region of first 6–8 thecae strongly dorsally curved, curvature decreasing distally. Extreme proximal end delicate in appearance, straight to slightly ventrally curved. Details of sicula obscure, but apparently it is weakly ventrally curved. Ventral walls of thecae parallel to rhabdosome axis, thecal hoods small, strongly curved and almost lobate, thecal hoods occupying no more than one-sixth of rhabdosome width. Intertheal septa marked only by weak ridges perpendicular to rhabdosomal axis. Thecae spaced about 6–6.5 in 5 mm. Proximal region 0.3–0.4 mm wide, distal region width, including thecal hood, about 1 mm.

Discussion. The Arctic subspecies differs from known subspecies such as *Monograptus microdon microdon* Richter, 1875, *Monograptus microdon silesicus* Jaeger, 1959, and *Monograptus microdon aksajensis* Koren', 1983, in possessing a strongly dorsally curved proximal region. The presence of very small and strongly incurved thecal hoods appears to be a characteristic of the *Monograptus microdon* group.

The age of the Arctic subspecies is in doubt since it has been found only in association with *M. birchensis*. Of the previously described subspecies, only *Monograptus microdon aksajensis* is definitely known to occur in the Pridoli, whereas *Monograptus microdon microdon* and *Monograptus microdon silesicus* occur in Lower Devonian strata.

Monograptus cf. *uncinatus* Tullberg, 1883

Pl. 38, figs. 12–15; Pl. 45, figs. 7–10; Pl. 29, fig. 12?

cf. 1883 *Monograptus uncinatus* Tullberg; p. 30, pl. 1, figs. 24, 25.

cf. 1958 *Monograptus uncinatus* Tullberg; Urbanek, p. 48, text-fig. 21; pl. 1, fig. 3.

cf. 1986 *Monograptus uncinatus* Tullberg; Jaeger, fig. 43.

cf. 1997a *Monograptus (Uncinograptus) uncinatus* Tullberg; Urbanek, p. 156, pl. 7, fig. 5; pl. 8, figs. 9, 10.

?1998 *Monograptus uncinatus praeprognatus* Rickards and Sandford; p. 759, figs. 10c, d.

Types. Illustrated in Tullberg 1883, pl. 1, figs. 24, 25, from the Ludlow of the Scania region, Sweden.

Study material. Rare, moderately preserved, flattened specimens from TC #3, and a single isolated fragment tentatively identified from SB-D, 75 m.

Description. Rhabdosome essentially straight throughout, and with a straight to slightly ventrally curved sicula possessing a long, straight virgella. Rhabdosome widening gradually from about 0.6–0.7 mm across theca 1, to 1.1 mm across theca 5, to a maximum of 1.5–2.0 mm, all inclusive of thecal hoods. Thecae with strong thecal hoods throughout, although distal hoods slightly weaker than proximal ones; hoods occupying about one-fifth rhabdosome width. Intertheal septa sigmoidal, overlapping somewhat distally. Thecae 6.5–7 in 5 mm proximally, 5–6 in 5 mm distally.

Discussion. This is the first tentative recognition of *M. uncinatus* in the Arctic, although limited material and relatively poor preservation makes identification uncertain. Nevertheless, the essentially straight rhabdosome, strong thecal hoods throughout, and more or less straight sicula are features characteristic of the species.

The Arctic material might be assignable to *M. uncinatus praeprognatus* Rickards and Sandford, 1998, with its distal decrease in size of the thecal hoods, and the slight overlap of the distal intertheal septa, but the Australian material is shown only as line drawings, and comparison is difficult.

Genus *Colonograptus* Přibyl, 1942

Type species. *Graptolithus colonus* Barrande, 1850, p. 42, pl. 2, figs. 2, 3. From the Ludlow of the Barrandian region, Czech Republic.

Diagnosis. Monograptid with bifurc thecae; proximal two or three thecae with ventrally projecting microfusellar, broad, spine-like lappets, distal thecae simple tubes. Sicula generally with a ventral curvature.

Remarks. The genera *Colonograptus* and *Saetograptus* are used in the sense of Přibyl (1942), and Urbanek (1958); that is, the former possesses one to several proximal thecae with fairly pronounced and long, but rounded lateral lappets, and distal simple tubular thecae, whereas the latter is characterized by its possession of long and spine-like lateral lappets that often range through the entire length of the rhabdosome.

Colonograptus colonus heathcotensis (Rickards and Sandford, 1998)

Pl. 27, figs. 1–7, 9; Pl. 35, figs. 1–5, 7

1990 *Saetograptus roemeri* (Wood); Lenz, figs. 3J, Z.

1992 *Colonograptus colonus* (Barrande); Lenz, p. 201, pl. 1, figs. D–H

1998 *Saetograptus colonus heathcotensis* Rickards and Sandford; p. 760, figs. 9a–e.

Type. National Museum, Victoria, holotype NMV P146326 (fig. 9a), from the Ludlow, Heathcote area, Victoria, Australia.

Study material. Abundant, in flattened and isolated form. Flattened material from CP 1590'; SJF (147, 148, 163', 170, 172 m); GP (10.5, 20, 22 m); HH (55.5', 60, 61.5, 72 m); TC #3, 3B, TWW (15.1, 23.8, 32.5, 35, 38.5 m). Isolated material from AB2-99 (23', 30 m); BH 82.5 m; BH2 (116,

118, 128, 146.5, 147, 149 m); SB-90, 5 m; SB-97A (1.5, 2 m).

Description. Rhabdosome long, moderately ventrally curved through the distance of sicula and first two to four thecae, and gently, but distinctly dorsally curved through most, or all, of the distal region. Sicula ventrally curved, 2.1–2.4 mm long, apex about level with hood of theca 2, possessing long (ca. 0.6–0.7 mm) virgella. Thecae essentially tube-like and inclined at about 30°–40° to rhabdosome axis, but with well-developed lappets on proximal several thecae. Proximal lappets strongly projecting, almost beak-like in profile; lappets strongest and longest on theca 1, and quickly becoming progressively shorter distally. Thecae about 8 in 5 mm proximally and about 6–6.5 in 5 mm distally. Rhabdosome 0.9–1.2 mm wide across theca 1 (isolated material), 1.4–1.5 mm across theca 5 (isolated), with a maximum of about 2 mm distally (flattened material).

Discussion. This subspecies, as described by Rickards and Sandford (1998), differs from typical *Colonograptus colonus* (Barrande, 1850) in possessing more closely spaced thecae, and in being dorsally curved through most its length, a feature that distinguishes it from *S. colonus compactus* (Wood, 1900) that is slightly ventrally curved. The Arctic material would appear to differ from the Australian in possessing less closely spaced distal thecae, although a count of the distal thecae spacing on Rickards and Sandford's (1998) illustrations show that thecal spacing on their material decreases distally to about 6 in 5 mm, that is, the same as in the Arctic material. This subspecies is overall very like *C. roemeri* (Barrande, 1850), a species that is also distinctly dorsally curved, but differs in being much narrower (2 mm vs. 3 mm).

Genus *Saetograptus* Přibyl, 1942

Type species. *Graptolithus chimaera* Barrande, 1850, p. 52, pl. 4, figs. 34, 35. From the Ludlow of the Barrandian region, Czech Republic.

Diagnosis. Monograptids with basically tube-like thecae, some or many of which bear long, narrow, and spine-like lateral lappets composed of microfusellar layers. The long and spine-like character of the lappets distinguishes this genus from *Colonograptus*.

Saetograptus linearis (Bouček, 1936)

Pl. 27, figs. 8, 10–18; Pl. 38, figs. 2, 11

1936 *Monograptus fritschii linearis* Bouček; p. 148, figs. 3r–u.

1942 *Pristiograptus* (*Saetograptus*) *fritschii linearis* (Bouček); Přibyl, p. 17, text-fig. 3, figs. 19–21.

1979 *Monograptus fritschii linearis* Bouček; Jaeger and Robardet, pl. 1, fig. 6.

1986 *Saetograptus fritschii* cf. *linearis* (Bouček); Lenz and Melchin, p. 1854, fig. 1.

1988 *Saetograptus fritschii linearis* (Bouček); Lenz, p. 367, figs. 3S–X.

1990 *Saetograptus fritschii linearis* (Bouček); Lenz, figs. 3S–U.

1992 *Saetograptus fritschi linearis* (Bouček); Lenz, p. 206, pl. 2, figs. A–G.

1995 *Saetograptus fritschi linearis* (Bouček); Rickards, Holland and Serpagli, p. 74, text-figs. 4a, b, 9b.

1997 *Saetograptus fritschi linearis* (Bouček); Zhang and Lenz, p. 1230, figs. 4U, 4BB–4FF, 5O–5Q.

Types. Illustrated in Bouček 1936, figs. 3r–u, of which fig. 3u is the holotype; from the Ludlow of the Barrandian region, Czech Republic.

Study material. Moderately common in flattened form. From AB2-99 (39, 110.5, 116, 125 m); CP [1850' (563.9 m), 1925' (586.7 m)]; GP (38, 39.5 m); IB #2; SBC #7A, 7C; SB-D, 325 m; TWN (0, 1.5 m). Dozens of isolated fragments from SB97, D#2.

Discussion. This species has been widely recognized in Yukon and the Arctic Islands, both in flattened form and, in the case of the Arctic, in both flattened and isolated, uncompressed form. Its morphology is, therefore, well known and described (see Lenz 1992). Characteristics of the species include a sicula with a distinctly flaring aperture and a long, dorsally or dorso-proximally projecting sicula dorsal spine, and long and bifurcating or trifurcating thecal spines.

The species is rather similar to Baltic material identified as *Saetograptus* cf. *leintwardincensis* by Maletz (1997). It differs in having a generally much more flaring sicula aperture, a long and dorsally projecting sicula dorsal spine rather than an incurved, single or two-pronged dorsal process, and in possessing bifurcating or trifurcating thecal spines.

Saetograptus varians (Wood, 1900)

Pl. 28, figs. 1–5; Pl. 35 figs. 8, 9, 11;

Pl. 43, figs. 7–10

1900 *Monograptus varians* Wood; p. 467, figs. 15a–c; pl. 25, figs. 14A, B.

1910 *Monograptus varians* Wood; Elles and Wood, p. 395, figs. 263a–c; pl. 39, figs. 6a–c.

1942 *Pristiograptus (Colonograptus) varians varians* (Wood); Přibyl, p. 6, figs. 2.10, 2.11.

1969 *Saetograptus varians* (Wood); Hutt, p. 363, figs. 1A–C.

Type. Illustrated in Wood 1900, pl. 25, fig. 14A; from the Ludlow of Wales.

Study material. Uncommon, moderately to poorly preserved material from GP 10.5? m; HH (60, 61.5, 66? m); tentatively identified in isolated form from BH 86 m. Several well-preserved, isolated specimens from field collection TC 312, northeastern Cornwallis Island.

Description. Rhabdosome relatively long, and straight except for a weak dorsal curvature through the levels of thecae 2–4, and gently ventrally curved in the region of sicula and theca 1. Sicula about 1.4–2 mm long, apex almost to, or level with, theca 2 aperture, sometimes with proximally projecting, weak to moderate dorsal lip. Thecae bifurcating, inclined about 30° throughout; proximal one to three thecae with spine-like thecal lateral lappets, lappets of theca 1 being strongest and most ventrally projecting, thecae 2 and 3 generally with moderately developed lappets, and remaining thecae simple pristiograptid tubes. Thecae spaced 7–8 in

5 mm proximally, and 6–6.5 in 5 mm distally. Rhabdosome 0.7–0.8 mm across theca 1, reaching a maximum of about 1.1–1.2 mm about level of theca 8–10, and of constant width distally.

Discussion. This species, not previously recognized with certainty in the Arctic, has been known from the beginning of the twentieth century (Wood 1900), but it was only following Hutt's (1969) study of full-relief material that its morphology became well understood. That study showed that only the proximal two to three thecae bear spine-like lappets, typical of the genus *Saetograptus*. The Arctic specimens, though limited in quantity, closely resemble the typical material, with the exception that generally, only theca 1 bears strong spine-like lappets.

Genus *Neocolonograptus* Urbanek, 1997

Type species. *Monograptus ultimus* Perner, 1899, p. 13, figs. 14a, b. From the Pridoli of the Barrandian region, Czech Republic.

Remarks. Urbanek (1997a) defined the genus as "Pristiograptids with bilobate apertural elaborations, ranging from gentle undulations to strong lappets oriented antero-laterally. Ventral walls of thecae sigmoidal or straight." The genus is further characterized by the possession of a fairly complex sicula that may be moderately to strongly ventrally curved and which possesses a strong (rutellum), or may show a trumpet-like flare at its distal end, with or without a dorsal tongue. The characteristics of the sicula are particularly useful in distinguishing *Neocolonograptus* from the, otherwise, rather similar lappet-bearing late Homeric and early Ludlow genus *Colonograptus*.

Neocolonograptus branikensis (Jaeger, 1986)

Pl. 42, figs. 1–3, 13; Pl. 46, figs. 17, 19–21

1986 *Monograptus branikensis* Jaeger; p. 325, text-fig. 40; pl. 1, figs. 10, 12, 14.

1990 "*Monograptus*" *branikensis* Jaeger; Lenz, fig. 4F–H.

1997a *Neocolonograptus lochkoviensis branikensis* (Jaeger); Urbanek, p. 168, pl. 23, figs. 1–4.

1997 *Monograptus branikensis* Jaeger; Koren' and Sujarkova, p. 73, pl. 2, fig. 10; pl. 3, figs. 1–11; text-figs. 10A–W.

Type. Illustrated in Jaeger 1986, pl. 1, fig. 10 (Czech Geological Survey type no. HJ 54), from the Pridoli of the Barrandian region, Czech Republic.

Study material. Uncommon and found only in flattened form. From GP 80.5 m; HH 126 m; TC #18, #20; TWN 35 m (talus collection) and, tentatively, SF 38 m.

Description. Rhabdosome short, with weak ventral curvature in sicula region, sometimes weak dorsal curvature in region of thecae 2–3, and straight distally. Sicula weakly ventrally curved, apex slightly below or at level of theca 2 aperture, 2.0–2.3 mm long. Thecal free portion formed of long lappets, beak-like in profile, more or less maintaining length through at least first 10 thecae, free portion occupying fully one-third of rhabdosome width. Thecae numbering 6–6.5 in

5 mm proximally and about 5.5 in 5 mm distally. Intertheal septa sigmoidal, not overlapping. Rhabdosome width 1.0–1.1 mm across theca 1, maximum width 1.3–1.5 mm.

Discussion. The Arctic specimens resemble the type in essentially all characteristics, including the total lack of overlap of the intertheal septa, the main feature that, according to Jaeger (1986, p. 326), distinguishes it from the otherwise very similar *N. lochkoviensis* (Přibyl, 1940).

Neocolonograptus norfordi (Lenz and Jackson, 1971)

Pl. 41, figs. 4–7; Pl. 46, figs. 3–5

1971 *Monograptus norfordi* Lenz and Jackson; p. 11, pl. 1, figs. 7–10; text-figs. 3E, F, J, K, L.

Types. Holotype GSC 21304 (fig. 10) and paratypes 21305–21310, from the lower Pridoli of Hart River, Yukon.

Study material. Only a few, poorly preserved specimens from collection 5–8, and tentatively from collection 9–3, both Judge Daly Promontory, Ellesmere Island, the latter material associated with *Formosograptus formosus*.

Discussion. This species has been previously recognized only in northern Yukon (Lenz and Jackson 1971) where it is associated with *N. ultimus*, pointing to an Early Pridoli age. The Arctic association with only *Formosograptus formosus* suggests either a latest Ludlow or earliest Pridoli age.

The Arctic specimens, like those from Yukon, are short with a weakly ventrally curved sicula region, and a continuously dorsally curved distal region. Although difficult to say conclusively, the beak-like or rounded profile of the apertures of thecae 1 and 2 suggests that they possess lappets similar to those seen in *N. parultimus*. As in the Yukon material, proximal width is 0.8–0.9 mm, distal maximum width is about 1 mm, and thecae are spaced about 7 in 5 mm.

Neocolonograptus parultimus (Jaeger, 1975)

Pl. 34, figs. 12–16, 20–23; Pl. 41, figs. 8–12, 14;

Pl. 46, figs. 6–8, 13

1975 *Monograptus parultimus* Jaeger; p. 119, text-fig. 4; pl. 2, figs. 4, 8.

1976 *Pseudomonoclimacis ultimus* (Perner); Tsegelnyuk, p. 106, pl. 30, figs. 10–12.

1976 *Pseudomonoclimacis podolicus* Tsegelnyuk; p. 106, pl. 31, figs. 1–3.

1979 *Monoclimacis ultimus* (Perner); Paškevičius, p. 160, pl. 10, figs. 1–5; pl. 24, figs. 16–19; pl. 25, figs. 1–5.

1986 *Monograptus parultimus* Jaeger; Jaeger, p. 318, text-figs. 29–24; pl. 1, figs. 1, 2, 5, 8, 9; pl. 2, figs. 3–6, 23, 24; pl. 4, fig. 12.

1990 *Pseudomonoclimacis ultimus* (Perner); Lenz, figs. 4J–L.

1995 *Monograptus parultimus* Jaeger; Rickards, Holland and Serpagli, p. 74, text-figs. 6a–c, 9c.

1997a *Neocolonograptus parultimus* (Jaeger); Urbanek, p. 166, pl. 21, fig. 48.

1997 *Monograptus parultimus* Jaeger; Koren' and Sujarkova, p. 78, pl. 4, figs. 5–12; pl. 5, figs. 1–7; text-figs. 12A–Y.

1999b *Monograptus ultimus* Perner; Rickards and Wright, p. 195, figs. 3Q–S, U.

Types. Illustrated in Jaeger 1975, fig. 4a from the lower Pridoli of the Beroun area, Czech Republic.

Study material. Very common in flattened form. From CP 2260' (688.8 m)?; SJF (308?, 309?, 322? m); GP (54?, 56?, 56.5?, 57; 58.5, 66.5, 67.5, 70.5 m); HH (126, 132? m); IB (6, 19 m); TC #14, #15, #16; TWN (23.5, 24, 30?, 32 m); collection localities C198697; C198698; C207017; C207032. Uncommon isolated material in association with abundant *Neocolonograptus ultimus* from BH2, 492 m.

Description. Rhabdosome fairly long (up to 25 mm), may be gently ventrally curved through range of proximal seven to eight thecae, then straight thereafter. Width ranges from 0.8–0.9 mm across theca 1, 1.0–1.3 mm across theca 5, and to a maximum of 1.5–1.8 mm at about the level of thecae 12–14. Sicula generally gently curved in ventral direction, often with short, ventrally curved dorsal tongue, about 2 mm long, sicula apex level ranges from mid-region to hood of theca 2. Intertheal septa straight to weakly sigmoidal. Theca 1 and, sometimes thecae 2 and 3, with weak lappets, more distal thecae simple tubes, some thecae monoclinal. Thecae spaced 6–6.5 in 5 mm proximally, and 5 in 5 mm distally.

Discussion. The Arctic material agrees well with that from the Czech Republic, including the considerable numbers of variations noted by Jaeger (1986); these include the curvature of the sicula and its dorsal apertural tongue, and variation in the degree of formation, and number of proximal thecae with lappets. There appears to be a smooth gradation from more simple forms with almost pristiograptid thecae, to those with thecae very similar to *N. ultimus*, strongly suggesting an evolutionary continuum. The few isolated, in-relief specimens in association with abundant *Neocolonograptus ultimus* from BH2, 492 m differ slightly from the typical form in showing a less pronounced lappet formation in the proximal region, but are otherwise very similar.

Neocolonograptus? transgrediens (Perner, 1899)

Pl. 28, figs. 6–10; Pl. 42, figs. 8–12;

Pl. 46, figs. 9–12, 15, 16, 18

1899 *Monograptus transgrediens* Perner; p. 13, pl. 17, fig. 24.

1943 *Pristiograptus transgrediens transgrediens* (Perner); Přibyl, p. 30, pl. 2, fig. 7; pl. 3, fig. 7.

1964 *Pristiograptus transgrediens* (Perner); Teller, p. 52, pl. 2, fig. 3; pl. 3, figs. 1–4; pl. 7, figs. 8–12; text-figs. 11a, b.

1964 *Pristiograptus chelmiensis* Teller; p. 44, pl. 3, figs. 5, 6; pl. 4, figs. 1, 6–8; pl. 7, figs. 1–7; pl. 13, fig. 6; text-figs. 7a–c.

1964 *Pristiograptus separabilis* Teller; p. 49, pl. 2, figs. 2, 10; pl. 7, figs. 16, 17; text-figs. 9a–c.

1964 *Pristiograptus admirabilis* Teller; p. 47, pl. 5, figs. 1–4; pl. 8, figs. 4–7; text-figs. 8a–c.

1984 *Monograptus chelmiensis* (Teller); Porębska, p. 134, figs. 11; 1–12.

1984 *Monograptus transgrediens praecipuus* Přibyl; Porębska, p. 138, figs. 12; 1–7.

- 1984 *Monograptus transgrediens transgrediens* Perner; Porębska, p. 141, figs. 13: 1–9.
- 1986 *Monograptus transgrediens* Perner; Jaeger, p. 326, text-figs. 41a–c; pl. 1, figs. 15, 17–18; pl. 2, figs. 12, 16, 17, 19, 22, 25.
- 1986 *Monograptus transgrediens* Perner; Koren', p. 115, pl. 27, figs. 1–6; pl. 28, figs. 1–5; text-figs. 25a–i.
- 1990 "*Pristiograptus*" *transgrediens* (Perner); Lenz, figs. 4P–R.
- 1997 *Istrograptus transgrediens transgrediens* (Perner); Teller, p. 76, pl. 2, figs. 1–11.
- 2002 *Monograptus transgrediens* Perner; Sherwin and Rickards, p. 97, figs. 4E–I, 6A.

Type. Illustrated in Perner 1899, pl. 17, fig. 24, from the upper Pridoli of the Barrandian region, Czech Republic.

Study material. Abundant material in flattened form, ranging through a considerable stratigraphic interval. From CP 4430' (1350.3 m); GP (98, 105 m); HH 189' m; IB (41', 44', 55, 75, 102' m); SF (80', 90, 95, 100, 106', 112, 129, 159, 165, 198, 202, 216, 225', 231', 248', 264, 270, 305 m); TC (#21, #22, #23, #24, #25, #26, #27, #28, #29, #30); localities C198699; C207056; C146440; C146441. Eight isolated specimens are from C 11472, near Cape Manning on north-eastern Cornwallis Island.

Description. Rhabdosome may be very long (≥ 50 mm), essentially straight throughout, although between level of thecae 2–3, may be weakly dorsally curved. Sicula about 1.8–2.5 mm long, variable, ranging from a simple, ventrally curved cone with concave aperture profile, to one with weakly to strongly flaring trumpet-like aperture (see pl. 46, fig. 18); dorsal lip weakly to moderately developed, proximally projecting. Sicula apex ranges from midway between theca 1 and theca 2, to level with distal end of theca 2. Virgella about 0.7 mm long, projecting proximo-ventrally. Thecae generally distinctly triform: theca 1 typically with strongly developed and ventrally projecting, rounded paired lappets, thecae 2–3 with weak lappets, and distal thecae simple tubes, but with monoclimacid profile, inclined 30° – 40° . Intertheatal septa weakly sigmoidal. Thecae number 6–6.5 in 5 mm proximally, and about 5 in 5 mm distally. Rhabdosome width 0.8–1.1 mm across theca 1, 1.3–1.5 across thecae 5, and continuing to widen slowly but steadily to a maximum of 1.8–2.3 mm.

Discussion. Characteristics of this species include its considerably greater length and width, and more gradual widening as compared with *N. parultimus* or *N. ultimus*, great range of variability of the sicula, and the more or less confinement of strong lappet development to the first three thecae, especially the well-developed and ventrally projecting lappets of theca 1. The Arctic material shows considerable similarity to what was described as *Monograptus prognatus* Koren', 1983, by Sherwin and Rickards (2002), but is only slightly more than half its distal width.

This species was assigned to the genus *Istrograptus* by Tsegelnyuk (1988) and subsequently by Urbanek (1997a) and Teller (1997), although none provided morphological data sufficient to justify the recognition of the genus. While we fully recognize that *transgrediens* may well have arisen independently as a later derivation from some *dubius* stock,

as probably did early Pridoli taxa *Neocolonograptus parultimus* and *N. ultimus* (e.g., Urbanek 1997, p. 111), this is not considered here to be justification for assigning it to a new genus without supporting morphological criteria. For this reason then, a conservative approach is taken, and *transgrediens* is tentatively assigned to the genus *Neocolonograptus*.

Neocolonograptus ultimus (Perner, 1899)

- Pl. 34, figs. 8–11, 17–19; Pl. 42, figs. 4–7, 14, 15;
Pl. 46, figs. 14, 22–24; Pl. 41, fig. 13?;

- 1899 *Monograptus ultimus* Perner; p. 13, text-figs. 14a, b.
- 1964 *Pristiograptus aduncus* Teller; p. 42, pl. 1, figs. 4–6; pl. 2, figs. 1, 6; pl. 7, figs. 18, 19; pl. 9, figs. 4–9; text-figs. 5a–d.
- ?1964 *Pristiograptus rarus* Teller; p. 38, pl. 1, figs. 1–3; pl. 9, figs. 10–12; text-figs. 3a–c.
- 1969 *Monograptus hugensius* (Teller); Jackson and Lenz, p. 23, pl. 3, figs. 1–4; pl. 5, figs. 2–4.
- 1976 *Skalagraptus vetus* Tsegelnyuk; p. 101, pl. 32, figs. 2–5.
- 1986 *Monograptus ultimus* Perner; Jaeger, p. 321, text-figs. 35a, b; 36a–c; 37a–d; 38; pl. 1, figs. 3, 4, 7, 11, 13; pl. 2, figs. 7, 8.
- 1990 *Pseudomonoclimacis ultimus* (Perner); Lenz, figs. 4V–Z.
- 1997a *Neocolonograptus ultimus* (Perner); Urbanek, p. 167, pl. 22, figs. 1–5.
- 1997 *Monograptus ultimus* Perner; Koren' and Sujarkova, p. 85, pl. 8, fig. 8; text-figs. 17A–H, K–L, N–O.

Types. *Monograptus ultimus* Perner, 1899, p. 13, figs. 14a, b. From the Pridoli of the Barrandian region, Czech Republic.

Study material. Common in flattened form; preservation ranging from very good to fair. From SJF (314, 394, 439 m); GP (57.5, 75', 80.5, 84, 88, 94 m); HH (126, 139.5, 148.5, 156, 166.5 m); IB (32, 33, 36, 58, 79 m); SF 50 m?; TC #17, #18, #19; TWN 35 m (talus collection); locality C198699. Extremely abundant and well preserved, isolated material from BH2, 492 m.

Description. Rhabdosome small, seldom more than 20 mm long, gently dorsally curved between levels of thecae 5–8, and straight distally. Sicula generally ventrally curved and with ventrally curved dorsal margin, with short dorsal apertural tongue, 1.7–2.5 mm long, apex about level with tip of theca 2. Thecae biform, proximal 3–6 with well-developed lateral lappets, especially prominent on thecae 1–3, distal thecae more tube-like, inclined about 30° , overlapping one-half to two-thirds distally, moderately monoclimacid in profile. Thecae spaced 5.5–6 in 5 mm proximally, and 4.5 in 5 mm distally. Rhabdosome 0.8–1.0 mm wide across theca 1 (isolated material), 1.0–1.3 mm across theca 5, with a maximum of 1.5 mm distally (flattened material).

Discussion. The most variable feature of this species is the strength of development of thecal lappets, and the number of thecae bearing lappets. This feature has been well discussed and illustrated by Jaeger (1986). The material from the Arctic agrees very well with material from Poland (Urbanek 1997), especially in the nature of lappet development. The species is very similar to *Pseudomonoclimacis latilobus* (Tsegelnyuk, 1976), but according to Urbanek (1997) that spe-

cies differs from *N. ultimus* in being more robust, and in possessing lateral incisions along the thecal apertural margin.

Genus *Bohemograptus* Přibyl, 1967

Type species. *Graptolithus bohemicus* Barrande, 1850, p. 40, pl. 1, figs. 15–18. From the Ludlow of the Barrandian region, Czech Republic.

Emended diagnosis. Monograptids with a distinct or strong ventral curvature of the rhabdosome. Thecae broad and subtriangular, with straight or gently elevated apertural margins, either devoid of or provided with microfusellar additions forming broadly lobate, annular or tape-like apertural structures. Sicular rather robust (from Urbanek, 1970, p. 265).

Remarks. *Bohemograptus* is among the most common monograptid in the lower and middle Ludlow of the Arctic (and Yukon) sequences. It appears at or very near the base of the Ludlow, and ranges well into the upper Ludlow. The grade from the earlier *Bohemograptus bohemicus bohemicus* to the later descendant *Bohemograptus bohemicus tenuis* is essentially a seamless continuum. Rickards and Wright (1999a) suggest that Australian morphs of the latter subspecies become more gracile up the stratigraphic column. The Arctic sequence provides only weak support for the suggested trend. Other members of the *Bohemograptus* group are much less common in the Arctic. *Bohemograptus garratti* occurs in the lower Ludlow, unlike its higher occurrence in Australia (Rickards et al. 1993), and *Bohemograptus helicoides* and *B. praecornutus* occur rarely, and uncommonly, respectively, in the middle and lower upper Ludlow. *Bohemograptus cornutus* Urbanek, 1970, and *Egregiograptus pribyl* Rickards and Wright (1999), while not yet found in the Arctic, occur in northern Yukon (Jackson and Lenz 1972; Lenz 1984, respectively). Since the graptolite faunal content in the two regions is almost identical (see discussion in Zonal Correlation, Species Diversity and Biogeography), the occurrence of the two species in the Arctic can reasonably be expected.

Bohemograptus bohemicus bohemicus (Barrande, 1850)

Pl. 37, figs. 1–5, fig. 7?; Pl. 44, figs. 1–5; Pl. 37

1850 *Graptolithus bohemicus* Barrande; p. 40, figs. 15–18.

1970 *Bohemograptus bohemicus bohemicus* (Barrande); Urbanek, p. 267, pl. 10; pl. 13, fig. C; pl. 20, fig. A; Figs. 10, 11.

1976 *Bohemograptus bohemicus* (Barrande); Tsegelnyuk, p. 126, pl. 39, figs. 7–10.

1990 *Bohemograptus bohemicus bohemicus* (Barrande); Lenz, figs. 3A, B.

1995 *Bohemograptus bohemicus bohemicus* (Barrande); Rickards, Packham, Wright, and Williamson, fig. 31K.

1997 *Bohemograptus bohemicus bohemicus* (Barrande); Zhang and Lenz, p. 1236, figs. 6M–6S, 7I, 7K–7M.

1999a *Bohemograptus bohemicus bohemicus* (Barrande); Rickards and Wright, fig. 2B.

Types. *Graptolithus bohemicus* Barrande, lectotype L17762; figured by Barrande (1850, p. 40, pl. 1, figs. 15–18). From the lower Ludlow of the Barrandian region, Czech Republic.

Study material. Moderately common and well to moderately preserved in flattened form. From CAR 4A, 5A, 5B; SJF (149.5, 151, 154, 163, 166 m); HH (93, 99 m); SBC #4; TC #2, #3, #3A, #3B, #4; TWW (19.5, 25, 26.5, 30 m).

Discussion. This subspecies is among the more common Ludlow monograptids, and ranges through most of the lower and middle Ludlow. Common characteristics include a continuously ventrally curved rhabdosome in which curvature decreases distally, a 2.0–2.3 mm long sicular the apertural region of which may be slightly flared, and the possession of a long (up to 1.0 mm) ventro-proximally directed virgella.

Characteristically, and most importantly, the sicular apex is about level with or beyond the aperture of theca 2. The thecae are simple cylinders inclined 30°–40°, overlapping about one-half proximally and two-thirds distally, and spaced 6–6.5 in 5 mm proximally and 5–5.5 in 5 mm distally. Apertural rims, some of which may be slightly sigmoidal in profile, are generally inclined at less than 90° to the thecal axis, and that of theca 1 may be slightly convex in profile. Width across theca 1 is 0.6–0.7 mm, about 0.8 mm across theca 5, and up to 1.4–1.5 mm distally. A comparison with *Bohemograptus bohemicus tenuis* is given below.

Bohemograptus bohemicus tenuis (Bouček, 1936)

Pl. 31, figs. 17–25; Pl. 37, figs. 6, 8, 14;

Pl. 44, figs. 6–8, 14, 15

1936 *Monograptus bohemicus tenuis* Bouček; p. 138, pl. 1, figs. 4, 5.

1955 *Monograptus bohemicus* (Barrande); Kühne, p. 382, text-fig. 9A–J.

1958 *Pristiograptus bohemicus* (Barrande); Urbanek, p. 77, pl. 4, figs. 1–3; text-figs. 48, 50, 51.

1970 *Bohemograptus bohemicus tenuis* (Bouček); Urbanek, p. 275, pls. 11, 12; pl. 13, figs. A, B; pls. 14–19; pl. 20, fig. B, pls. 21, 22; text-figs. 12–15.

1976 *Bohemograptus tenuis* (Bouček); Tsegelnyuk, p. 129, pl. 41, figs. 1–5.

1990 *Bohemograptus bohemicus tenuis* (Bouček); Lenz, figs. 4A, B.

1992 *Bohemograptus bohemicus tenuis* (Bouček); Lenz, p. 201, pl. 1, figs. I–M.

1995 *Bohemograptus bohemicus tenuis* (Bouček); Štorch, p. 71, pl. 1, fig. 1; pl. 2, figs. 1, 2, 5; pl. 3, fig. 7; text-figs. 3D, G, H, J, M; text-figs. 4B, C.

1997 *Bohemograptus bohemicus tenuis* (Bouček); Zhang and Lenz, p. 1236, figs. 6V–6Z, 6AA, 7A–7E.

1999b *Bohemograptus bohemicus tenuis* (Bouček); Rickards and Wright, figs. 4X, 5A, B.

Type. Illustrated in Bouček 1936, pl. 1, fig. 5. From the Lower Ludlow of the Reporyje beds, Barrandian region, Czech Republic.

Study material. Common in flattened form, well to moderately preserved. From AB2-99 (39, 42, 90, 106, 108, 116,

125 m); CP 2075'; SJF (211, 221.5, 284, 290, 291.5, 293, 294, 295 m); GP (39.5, 41, 45 m); TC (5, 7, 8, 9, 10, 11); TWW 32.5 m?; TWN (0, 1.5, 5.5, 7, 12.5, 18 m). Isolated material from BH2-98, 180 m; MCM91-029; tentatively SBC D2.

Description. Rhabdosome moderately and ventrally curved throughout, curvature decreasing distally. Sicula a straight cone to slightly ventrally curved on dorsal wall, aperture often slightly flaring, apertural wall curved and oblique with sometimes, a well-developed dorsal wall tongue. Sicula 1.9–2.6 mm long, apex generally about level with aperture of theca 1, but fairly often below or, rarely, almost midway between thecae 1 and 2. Virgella up to 1.3 mm long, directed proximo-ventrally. Thecae simple tubes, inclined 15° proximally and up to 30° distally, ventral walls straight to slightly concave, thecae overlapping only about one-quarter to one-third proximally and about one-half distally, spaced about 5.5 in 5 mm proximally and 4.5 in 5 mm distally. Apertural margins slightly rounded in profile proximally and in isolated material can be seen to have weak lappets, inclined at angle less than 90° to thecal axis. Width across theca 1 (isolated material) 0.55–0.8 mm, 0.8–1.0 mm across theca 5, and 1.0–1.3 mm distally (flattened material).

Discussion. This subspecies differs from its most closely related subspecies *B. bohemicus bohemicus*, in being altogether more delicate in appearance. Specifically, the rhabdosome width is less, thecal overlap is considerably less, especially proximally, the sicula more often manifests apertural flaring, and the apex of the sicula seldom extends beyond the level of the aperture of theca 1. Nevertheless, end members of the two subspecies completely overlap, and there can be little doubt that *B. b. tenuis* was derived from *B. b. bohemicus*. The stratigraphic overlap between the typical form, and this subspecies is considerable, sometimes most or all of the middle Ludlow (*linearis-ceratus* Biozone), and very occasionally some of the upper Ludlow *tenuis-praecornutus* Biozone.

Bohemograptus garratti Rickards, Davidson, and Banks, 1993

Pl. 37, figs. 9, 10, 15, 16; Pl. 44, figs. 9–11

1990 *Lobograptus* sp., Lenz, Figs. 3C, D.

1993 *Bohemograptus bohemicus garratti* Rickards, Davidson, and Banks; p. 131, figs. 3W, X; 7D.

1995 *Bohemograptus garratti* Rickards, Davidson, and Banks; Storch, p. 72, pl. 1, figs. 2, 3, 5, 6; text-figs. 3A, B, E, F, L.

Types. University of Tasmania, Department of Geology Holotype UTGD124382ai and paratypes UTGD124317bi and 124382biii from the Ludlow of Tasmania.

Study material. Uncommon and only moderately preserved as flattened specimens on shale. From SJF (290, 297 m); GP 22 m; TC #3.

Description. Rhabdosome very delicate, moderately to strongly ventrally curved. Sicula a straight cone, or with slightly flaring aperture, 1.3–1.8 mm long, apex at or beyond level of theca 1 aperture. Thecae inclined only about 10°–

15° proximally and 20° distally, overlapping one-quarter proximally and less than one-half distally, ventral margin straight to weakly monoclinal, apertural margins about perpendicular to long axis. Thecae 4.5–5 in 5 mm. Rhabdosome width 0.3–0.5 mm across theca 1 and about 0.9 mm distally.

Discussion. The Arctic representatives, although occurring in strata older than those in Australia, appear to match well with most characteristics of the Australian forms. However, because the species is so distinct from typical *B. bohemicus*, we follow Storch (1995) in treating it as a full species. This species is superficially like *Lobograptus jeremii* Rickards et al., 2003 (originally described as *Bohemograptus urbaneki* Rickards et al., 1995, but that name was subsequently found to be already in use for the earlier-named *Bohemograptus urbaneki* Tsegelnyuk, 1976), but differs in possessing a longer sicula, and apparently less geniculated thecae. These same features distinguish *B. garratti* from *Cucullograptus* (*Lobograptus*) progenitor *cadalensis* Rickards et al. (1995).

Bohemograptus? helicoides (Jackson and Lenz, 1972)
Pl. 40, figs. 6–8; Pl. 43, figs. 15–19

1972 *Monograptus helicoides* Jackson and Lenz; p. 590, text-figs. 2A, B, D, F, H, L.

Types. Holotype GSC 30122 and paratypes GSC 30123–30127, from the Upper Ludlow of the Hart River, Yukon.

Study material. Several, poorly preserved specimens from collection locality C199111, Walker River. Associated only with *Bohemograptus bohemicus* (s.l.).

Discussion. This species, recognized previously only in Yukon (Jackson and Lenz 1972), is unique among monograptids in possessing apparently simple bohemiograptid thecae, and being coiled in a tightly and ventrally curved spiral. In neither the Yukon nor Arctic specimens, however, are the thecae well enough preserved to clearly ascertain their nature, although in both cases they are fairly obviously simple and tube-like. Nevertheless, so distinctive is the species that its identification is not in doubt. The only other species with such a strong ventral curvature is *Cochlograptus veles* (Richter, 1871), but that species is considerably smaller, and has much more complex thecae and a much tighter coil.

In Yukon, the species is associated with middle to upper Ludlow species, and in the absence of biostratigraphically definitive associated species in the Arctic, its age there is assumed to be comparable.

Bohemograptus praecornutus Urbanek, 1970
Pl. 37, figs. 11–13, 17–19; Pl. 44, figs. 13, 19–22

1970 *Bohemograptus praecornutus* Urbanek; p. 301, pl. 20, fig. C; pls. 23, 24; fig. 16.

1976 *Bohemograptus arcuatus* Tsegelnyuk; p. 128, pl. 40, figs. 6–9.

?1976 *Bohemograptus urbaneki* Tsegelnyuk; p. 129, pl. 40, figs. 10–12.

1990 *Bohemograptus praecornutus* Urbanek; Lenz, figs. 3Q, R.

- 1995 *Bohemograptus praecornutus* Urbanek; Štorch, p. 71, pl. 1, fig. 4; pl. 2, figs. 4, 7; text-figs. 3C, J; 4A, E, G.
 1997 *Bohemograptus praecornutus* Urbanek; Urbanek and Teller, pl. 4, fig. 9.
 1999b *Bohemograptus praecornutus* Urbanek; Rickards and Wright, p. 200, figs. 5C–L; 13K.

Types. Illustrated in Urbanek 1970, pl. 20, fig. C; pls. 23, 24, of which Pl. 23, fig. C1–3 is the holotype. From the Upper Ludlow of the Mielnik borehole, Poland.

Study material. Uncommon and only moderately well preserved in flattened form. From SJF (297?, 298 m); GP (45, 48 m); IB 31; TC #9; localities C198453; C207032.

Description. Rhabdosome robust, strongly ventrally curved. Sicula, about 2 mm long, apex level with region between thecae 1 and 2, medium to strong apertural flare, some with well-developed dorsal tongue. Thecae tube-like, ventral wall straight to, more commonly, concave, inclined about 30° proximally, increasing to 45°–50° distally, overlapping about one-third proximally increasing to one-half distally. Thecal profile beak-like, apertural margins forming a distinctly acute angle with thecal axis, rounded to strongly rounded and everted, possibly due in part, to microfusellar layering along the ventro-lateral margins of the distal parts of the thecae. Width 0.9–1.0 mm across theca 1, 1.1 mm across theca 5, and 1.5 mm distally.

Discussion. Distinctive of the species is the high inclination of the thecae, and the distinctly rounded thecal margins that are inclined at a noticeably acute angle to the thecal axis. The Arctic material is generally typical of the species. A few specimens show a more delicate and drawn out sicula region than normal, but these otherwise demonstrate the distal thecal profile typical of the species. This species and *B. bohemicus tenuis* appear to show considerable overlap, suggesting an evolutionary continuum.

Genus *Crinitograptus* Rickards, 1995

Type species. *Monograptus crinitus* Wood, 1900, p. 480, fig. 23, pl. 25, figs. 26a, b. From the Ludlow of Britain.

Diagnosis. See Rickards, 1995, p. 1107.

Crinitograptus operculatus (Münch, 1938)

Pl. 30, figs. 1–12

- 1938 *Barrandeograptus operculatus* Münch; p. 53, text-figs. 2a–c; pl. 8, figs. 1, 2, 5, 6, 11; pl. 9, figs. 4, 5.
 ?1938 *Pomatograptus* sp., Münch; text-fig. 4; pl. 7, figs. 6–11.
 ?1938 *Barrandeograptus huckei* Münch; text-fig. 2.3; pl. 8, figs. 3, 4, 7.
 1955 *Barrandeograptus operculatus* Kühne; p. 397, figs. 18A–F.
 pars 1995 *Crinitograptus crinitus crinitus* (Wood); Rickards, p. 1109, figs. 3.1, 3.3, 3.4.

Types. Illustrated in Münch 1938, text-fig. 2; pl. 8, figs. 2, 5, 6, [pl. 7, figs. 6, 8–11 (= *Pomatograptus*); pl. 8, figs. 3?, 4?, 7? (= *Barrandeograptus huckei*)]. Lectotype not yet designated. From Ludlow erratic nodules of north Germany.

Study material. Dozens of isolated and mostly distal fragments from AB2-99, 21 m, 22 m, and tentatively from 23 m and 30 m. Found in the progenitor Biozone.

Description. Rhabdosome represented by distal fragments only; fragments range in width from 0.28–0.37 mm across thecal aperture, and 0.39–0.51 mm across thecal hood. Thecae are elongate tubes that overlap only slightly, and widen very slowly distally except in the region of the aperture where they are moderately flared, both ventrally and laterally. Thecal hoods very variable, ranging from short, straight and ventrally projecting hoods that fully expose thecal aperture, to much longer, wider and down-curved hoods that may obscure thecal apertures. Thecal hoods rounded to heart-shaped or triangular in plan view, some showing distinct growth lines (pl. 30, fig. 7), and up to 0.35 mm in lateral width. Thecal spacing unclear because of fragmental nature of material; a single example shows spacing between two successive thecae to be 2.1 mm, i.e., extrapolated to only about three thecae in 5 mm.

Discussion. Considering the fragmental nature of the Arctic material, its morphological features agree fairly well with those of the types and, in particular, the width of the rhabdosome and thecal spacing. Furthermore, the thecal hoods appear to show similar structure, including a heart-shape plan view. However, comparison with "*Barrandeograptus*" *huckei* Münch, 1938, is difficult, although that species would appear to differ from *C. operculatus* in a much more rapid widening of the apertural region of the theca and a more ventral orientation of the aperture, and a hood more strongly downcurved and thus oriented at a much lower angle to the axis of the rhabdosome. On the basis of limited original material, however, it is not known whether this is a significant difference, or a case of intraspecific variation. Comparison with *C. crinitus* Wood, 1900, is also difficult. Rickards (1995) initially considered that species and *C. operculatus* to be conspecific, but later Rickards and Wright (1999b) reversed that decision, and considered them to be separate species, although offering no morphological criteria. Instead they (1999b) separated them on essentially biostratigraphic criteria, suggesting that *C. operculatus*, unlike *C. crinitus*, is a Pridoli species, based on its Australian occurrence. This is clearly incorrect, since the types of *C. operculatus*, as well as the material illustrated in Kühne (1955), are associated with well-recognized Lower Ludlow species. It would appear, however, that the thecal hoods in *C. operculatus* are longer than those in *C. crinitus*, and that the ventral thecal walls of the latter species are continuously inclined to the axis of the rhabdosome, whereas those of the former are more or less parallel except for abrupt widening of the apertural region.

Crinitograptus cf. *operculatus* (Münch, 1938)

Pl. 35, figs. 6, 10, 12–15; pl. 43, figs. 20–25

- cf. 1938 *Barrandeograptus operculatus* Münch; p. 53, text-figs. 2a–c; pl. 8, figs. 1, 2, 5, 6, 11; pl. 9, figs. 4, 5.
 1969 *Monograptus?* *crinitus* Wood; Jackson and Lenz, p. 26, pl. 3, fig. 10.
 ?1999b *Crinitograptus operculatus* (Münch); Rickards and Wright, p. 199, figs. 4P–R.

Study material. More than twenty flattened, mostly distal fragments from CP 2400' (731.5 m); tentatively identified from GP 56 m, 56.5 m, and 58 m. Found in lower Pridoli strata.

Description. Rhabdosome broadly dorsally curved, degree of curvature lessening distally. Sricula 1.5–1.6 mm long (seen only in two specimens), apex below level of theca 1 aperture. Thecae overlapping only slightly, ventral walls mostly parallel to rhabdosome axis, except for widening near apertural region, aperture opening directed more or less distally. Thecal hoods weak proximally, but long and uniform in strength distally, directed ventrally, and apparently broadened latero-ventrally. Width of rhabdosome across thecal aperture and across thecal hood, respectively, 0.25–0.3 mm and 0.3–0.35 across theca 1, and 0.6–0.7 mm and 1.0–1.2 mm distally. Thecae spaced about 3 in 5 mm.

Discussion. Although it is difficult to compare flattened and isolated Arctic material, the apparent difference between the flattened Pridoli forms and the isolated Ludlow material is in the length of the thecal hood. In the flattened material, the hoods are much longer and they appear to broaden latero-ventrally. These same differences would appear to distinguish the Arctic from the Pridoli form of Australia (Rickards and Wright 1999). On the other hand, the long and ventro-laterally widening of the thecal hoods in the Arctic Pridoli material appears to match well with that seen in the so-called *Monograptus? crinitus* from the Pridoli of Yukon described in Jackson and Lenz (1969).

Genus *Formosograptus* Bouček, Mihajlović, and Veselinović, 1976

Type species. *Monograptus formosus* Bouček, 1931, p. 300, text-figs. 9b–d. From the lower Pridoli of the Barrandian region, Czech Republic.

Formosograptus formosus (Bouček, 1931)
Pl. 40, figs. 3–5; Pl. 45, figs. 17, 19, 20

- 1931 *Monograptus formosus* Bouček; p. 8; p. 18; text-figs. 9a–d.
1967 *Monograptus formosus* Bouček; Jaeger, p. 286, pl. 14, figs. b, c.
1969 *Monograptus paraformosus* Jackson and Lenz; p. 27, pl. 4, figs. 1, 2, 4.
1976 *Formosograptus formosus* (Bouček); Bouček, Mihajlović, and Veselinović, p. 85, pl. 1, figs. 1–3; pl. 3, fig. 5; text-figs. 1a–f.
1976 *Tamlograptus convexus* (Příbyl); Tsegelnyuk, p. 114, pl. 35, figs. 1–5.
1976 *Tamlograptus formosus* (Bouček, 1931); Tsegelnyuk, p. 115, pl. 35, figs. 6, 7.
1976 *Monograptus paraformosus* Jackson and Lenz; Tsegelnyuk, p. 116, pl. 35, figs. 8, 9.
1986 *Monograptus formosus* Bouček; Jaeger, p. 316, text-figs. 28a–e; pl. 3, figs. 4, 5; pl. 4, fig. 13.
1990 *Monograptus formosus* Bouček; Lenz, fig. 41.

1997a *Monograptus (Formosograptus) formosus* Bouček; Urbanek, p. 134, pl. 4–6; pl. 7, figs. 1–4; pl. 8, figs. 7, 8; figs. 19A–C.

1997 *Monograptus formosus* Bouček; Koren' and Sujarkova, p. 75, pl. 4, figs. 1, 2; text-figs. 11A–F.

Types. Illustrated in Bouček 1931, text-figs. 9b, c. Specimen 9b chosen as lectotype by Příbyl 1948. From the lower Pridoli of the Barrandian region, Czech Republic.

Study material. Fairly common in flattened form from CP 2260' (688.85 m); SJF 394 m; GP (57, 67.5?, and 70.5 m); IB (6, 17, 19? m); TC #13; TWN (12.5?, 35 m (talus sample)); localities C207932, C207035. Ranging through uppermost Ludlow and lower Pridoli strata.

Description. Rhabdosome moderately curved in a dorsal direction throughout, curvature lessening distally. Sricula simple cone-shape to slightly flaring in apertural region, with weakly to moderately developed dorsal lip, about 1.2 mm long, apex below level of theca 1 aperture. Thecae uniform, triangulate in profile, metathecal portion long and isolate, with slightly reflexed apertures. Thecal hood appears to be broadened and beak-like, undoubtedly due to flattening of broad, laterally expanded thecal shield (see Urbanek 1997, pl. 6). Free metathecal portion of thecae occupies about 70% of rhabdosome width proximally and 50–60% distally. Thecae spaced 4.5–5 in 5 mm proximally and distally. Rhabdosome width about 0.9 mm proximally, increasing to 1.1–1.3 mm distally.

Discussion. This species can be confused with few others, and even moderate-sized fragments may be identified with some confidence. This is one of the few species to cross the Ludlow–Pridoli boundary without apparent change.

Genus *Neodiversograptus* Urbanek, 1963

Type species. *Pristiograptus (Pristiograptus) nilssoni* Barande, 1850, p. 51, pl. 2, fig. 16. From the Ludlow of the Barrandian region, Czech Republic.

Diagnosis. See Urbanek, 1963, p. 149.

Remarks. *Neodiversograptus nilssoni*, the type species for the genus, has never been recognized with certainty in either northern or Arctic Canada, and would appear to be rare throughout all of present-day North America, with the exception of Nevada (Berry and Murphy 1975). The tentative recognition of *Neodiversograptus cf. beklemishevi*, below, is the only presently known occurrence of the genus in the Ludlow of the Arctic.

Neodiversograptus? cf. beklemishevi Urbanek, 1963
Pl. 31, fig. 16

- cf. 1963 *Neodiversograptus beklemishevi* Urbanek; p. 162, pls. 5, 6; fig. 2.
?1993 *Linograptus orangensis* Rickards et al.; p. 60, figs. 33O, Q–T; 34E, F; 35A–H; 36C, D
cf. 1997b *Neodiversograptus beklemishevi* Urbanek; Urbanek, p. 238, figs. 3A–C, 4A

Types. Illustrated in Urbanek 1963, text-pl. 5 and 6, text-fig. 2, of which text-pl. 5, fig. C, is the holotype. From the Ludlow of the Mielnik borehole, Poland.

Study material. Several, isolated fragments from AB2-99, 58.5 m. From the *scanicus-parascanicus* Biozone.

Discussion. The very few available proximal fragments are only very tentatively assigned to *N. beklemishevi*, and it is primarily the fragment illustrated in plate 5, fig. 16, that is most similar. The sicula, seen in only two fragments (destroyed before being photographed), is less than 2 mm long, possesses a very weak apertural flare, and a well-developed virgella. A dorsal apertural spine is not visible. The thecae are long, thin tubes that barely overlap and that increase in width only very slowly distally, but with a slight flare in the apertural region, and attain a cross-apertural width of about 0.35 mm. The aperture has a distinct lip, its profile forms a distinctly obtuse angle with the axis of the theca, and it has very weakly developed lateral lappets. It is the apertural rim structures that appear to be most characteristic of *N. beklemishevi*.

The thecal and sicular characteristics of *Neodiversograptus beklemishevi* and *Linograptus orangensis* Rickards, et al., 1995, are remarkably similar, at least so far as can be determined in comparing flattened material (*orangensis*) with isolated, but fragmentary material (*beklemishevi*). The only obvious difference appears to be that *Linograptus orangensis* possesses multiple cladia, although Urbanek (1966) alludes to the possibility of multiple cladia in *Neodiversograptus beklemishevi*. The two might, therefore, be conspecific, and since the name *Neodiversograptus beklemishevi* would have precedence, that name is tentatively used in this study.

Genus *Lobograptus* Urbanek, 1958

Type species. *Monograptus scanicus* Tullberg, 1883, p. 26, fig. 38. From the Ludlow of the Scania region, Sweden.

Diagnosis. See Urbanek, 1958, p. 12.

Remarks. With the exception of the common and widespread *Lobograptus progenitor*, other species of the genus *Lobograptus* are very rare in the Arctic, in marked contrast to their diversity in, for example, the southern Baltic northeastern Poland region (e.g., Urbanek 1966; Urbanek and Teller 1997).

Lobograptus parascanicus (Kühne, 1955)

Pl. 40, figs. 1, 2; Pl. 43, figs. 26, 27;

Pl. 32, figs. 1-4?

1955 *Monograptus parascanicus* Kühne; p. 392, figs. 15A-D, 16A-I.

1958 *Lobograptus parascanicus* (Kühne); Urbanek, p. 74, text-figs. 43, 44.

1966 *Lobograptus scanicus parascanicus* (Kühne); Urbanek, p. 420, pls. 21-24; pl. 47, fig. 1.

1997 *Lobograptus scanicus parascanicus* (Kühne); Urbanek and Teller, pl. 3, figs. 1, 2.

Types. Illustrated in Kühne 1955, text-figs. 15A-D, 16A-I, in which 15A-C is the type. From concretions in the region of Berlin, Germany.

Study material. Uncommon in flattened form from SJF 175 m, probably locality C198514, and tentatively recognized in isolated form from SB97-D-2.

Description. Rhabdosome gently ventrally curved, sicular end not recovered. Width across thecal aperture 0.4-0.5 mm, longest fragment 20 mm, constant in width. Thecae long and narrow, ventral wall inclined at less than 5° to axis of rhabdosome, aperture with paired ventro-dorsally expanded lobes, which are ovate or kidney-shaped in profile. Thecae spaced about 5 in 5 mm.

Discussion. This species is characterized by its simple, paired, ovate apertural lobes. These structures are well seen in profile in the flattened material. A few isolated fragments are similar to *L. parascanicus*, but these possess apertural lobes that are simpler and less lobate than typical of the latter species. In particular, the specimens illustrated in plate 32, figs. 1, 3, and 4 may well be fragments of some species of *Linograptus*, or of *Lobograptus*.

Lobograptus progenitor Urbanek, 1966

Pl. 31, figs. 1-8, 10, 13-15; Pl. 36, figs. 1-5;

Pl. 43, figs. 1-6

pars 1911 *Monograptus Nilssoni* (Barrande); Elles and Wood, pl. 37, figs. 1a, b.

1966 *Lobograptus progenitor* Urbanek; p. 384, figs. 3, 4; pls. 11-14.

1971 *Cucullograptus (Lobograptus) progenitor* Urbanek; Palmer, p. 377, figs. 1, 2, 11-14.

1990 *Lobograptus progenitor* Urbanek; Lenz, figs. 3E, F.

1997 *Lobograptus progenitor* Urbanek; Zhang and Lenz, p. 1232, figs. 6A-6F, 7H, 7N-7P.

1996 *Lobograptus progenitor* Urbanek; Lenz, Chen, and Ni, p. 1398, figs. 3I; 5I, J, L, M.

Types. Illustrated in text-figs. 3, 4; pls. 11-14, in which pl. 14, fig. A, is the type. From the Ludlow of the Mielnik borehole, Poland.

Study material. Very common in flattened form from CAR1; CP 1470; GP (12, 1.5, 16? m); SJF (148, 149.5 m); HH (48, 55.5, 60, 61.5, 66, 72, 76.5, 105 m); SBC #4; TC #3A; TWW (15.1, 16.5, 18, 19.5 m), and uncommon in isolated form from SBC88-#4, 4 m; BH1-91, 57.6 m; SB97, A4.5 m; MCM 91.

Description. Rhabdosome distinctly S-shaped; weakly to moderately dorsally curved through first four or six thecae, and ventrally curved distally. Sicula straight, dorsal wall straight with a dorsal flare in apertural region, or weakly ventrally curved; may have up to three sicular annuli (see Lenz and Kozłowska-Dawidziuk 1998), apex about level with aperture of theca 1; aperture concave or sigmoidal in profile. Virgella directed proximally or proximo-ventrally, 0.9-1.35 mm long. Thecae inclined 10° proximally and 15°-20° distally, overlapping only one-quarter or less proximally and about one-third distally, straight to weakly monoclinal in profile. Apertural margin forming obtuse angle with

thecal axis, profile rounded, often with weak trough on ventral rim. Thecae spaced 4.5–5 in 5 mm proximally and 3.5–4.5 in 5 mm distally. Width 0.3–0.4 mm across theca 1, increasing very slowly to 0.6–1.0 mm distally.

Discussion. The S-shaped rhabdosome is particularly characteristic of this species (see Palmer 1971), and it is that feature, in addition to sicular characteristics, that readily separates it from *Neodiversograptus nilssoni* (Barrande, 1850). The two taxa had often been confused prior to the study of Palmer (1971) who, studying flattened material from Ireland, provided clear diagnostic criteria for their distinction. Consequently, material that Thorsteinsson (1958) identified as *N. nilssoni* from the Arctic is almost certainly *L. progenitor*. Although not a convincing trend, examination of this species through its relatively long stratigraphic succession in the Arctic, offers weak and equivocal evidence that the S-shape may become more pronounced up the stratigraphic column.

Lobograptus scanicus (Tullberg, 1883)

Pl. 32, figs. 5–12

1883 *Monograptus scanicus* Tullberg; p. 26, pl. 2, fig. 38.

1955 *Monograptus scanicus* Tullberg; Kühne, p. 391, figs. 14A–E.

1958 *Lobograptus scanicus* (Tullberg); Urbanek, p. 72, text-figs. 41, 42; pl. 2, figs. 5, 6.

1966 *Lobograptus scanicus scanicus* (Tullberg); Urbanek, p. 444, figs. 11, 12; pl. 27; pl. 47, fig. 2.

1997 *Lobograptus scanicus* (Tullberg); Zhang and Lenz, p. 1234, figs. 6J–6L.

Types. Illustrated in Tullberg, 1883, pl. 2, fig. 38. Holotype by monotypy. From the Ludlow of the Scania region, Sweden.

Study material. Occurs in two sections only, very well preserved in isolated, but very fragmentary, form; from AB2-99 (58.5, 61, 82? m), and RC01-1, 21 m.

Description. Thecae barely overlapping, ventral wall inclined about 2°–3° to rhabdosome axis; prothecae long and narrow, increasing in width only very slowly, comprising 80–90% of total thecal length; metatheca isolated, directed ventro-distally, aperture almost hidden by paired, more or less kidney-shaped lobes. From ventral view, left lobe sometimes smaller and more distally directed than right lobe; right lobe in some specimens, folded over aperture and extended down and ventrally, mostly covering ventral part of aperture. Width across thecal lobes 0.4–0.45 mm, although which part of rhabdosome unknown. Thecal spacing about 1 mm.

Discussion. This is the first positive identification of the species from the Arctic. However, the Arctic material shows considerable variation in the nature of the apertural lobes, ranging from forms with the characteristic more or less the same-sized, kidney-shaped metathecal lobes (pl. 32, figs. 6, 9, 10) to some forms that appear more akin to *Cucullograptus aversus* (Eisenack, 1942) or *C. hemiaversus* Urbanek, 1960. Considering that there is a limited amount of material, and that there is a complete gradation between the simpler

and more complex forms, the collections are treated as a case of intraspecific variation for the moment.

Genus *Linograptus* Frech, 1897

Type species. *Dicranograptus posthumus* Reinh. Richter, 1875, p. 267, pl. 8, figs. 2, 3.

Diagnosis. Rhabdosome composed of main stipe (procladium) with at least one and generally very numerous sicular cladia; virgella with virgellarium, thecae simple, without apertural processes (Bulman, 1970, Treatise on Invertebrate Paleontology, V135).

Linograptus posthumus tenuis Jaeger 1959

Pl. 36, figs. 8, 9; Pl. 44, figs. 12, 16–18

1959 *Linograptus posthumus tenuis* Jaeger; p. 153, pl. 8, figs. 1, 2 (see Jaeger 1959 for detailed synonymy up to 1959).

Types. Illustrated in Jaeger 1959, pl. 8, figs. 1, 2; holotype fig. 2. From the Lower Devonian of Thüringia, Germany.

Study material. Several or more flattened specimens from each collection; from CP 2175' (662.9 m); SJF 298 m; GP 56 m; HH (93?, 99?, 148.5 m); TC (#20, #27, #28, #29), and ranging through Ludlow and Pridoli strata.

Discussion. As is characteristic of the *Linograptus posthumus* group, several, or more simple, uniserial branches radiate out from a central point and attain lengths of at least 15 mm. Details of the development of branches or the sicular region are unclear, and as a result, virgellae, terminal disks, or dorsal sicula spines are not discernible. Thecae are poorly visible, but appear to be simple elongate tubes, spaced about 3 in 5 mm and inclined about 5° to the axis, and the stipes are about 0.3 mm wide. In these parameters, the Arctic material matches well the typical *Linograptus posthumus tenuis* Jaeger (1959), and differs from the more robust typical form with its more closely spaced thecae and broader stipes.

Genus *Prolinograptus* Rickards and Wright, 1997

Type species. *Prolinograptus packhami* Rickards and Wright, 1997, p. 226, figs. 9L, 10A.

Diagnosis. See Rickards and Wright, 1997, p. 225.

Prolinograptus packhami Rickards and Wright, 1997?

Pl. 2, figs. 1–7

?*Prolinograptus packhami* Rickards and Wright, 1997, p. 226, figs. 9K, L, N, O, 10A

Types. Illustrated in Rickards and Wright, 1997, figs. 9L, 10A. Holotype AMF81773a, b (fig. 9L, 10A). From the Lower to Upper Ludlow of the Barnby Hills Shale, New South Wales, Australia.

Study material. Five isolated and well preserved, but short post-sicular fragments from the Lower Ludlow of section RC01-1, 22 m.

Description. Fragments preserve no more than two successive, post-sicular thecae. Stipe fragments extremely thin, maximum width 0.17–0.19 mm across apertural part of thecae, thecae barely or not at all overlapping. Protheca relatively long and very thin, widening only very little distally, comprising about 80% of theca length; metathecal width increasing very rapidly but smoothly, inclined 30°–40°. Thecal aperture with distinct lip; apertural rim markedly convex in profile. Thecae spaced about 1.41–1.48 mm, extrapolated to 11.2–11.8 in 10 mm.

Discussion. The tentative assignment of the fragmentary Arctic study material to the genus *Prolinograptus* rests solely on its very close similarity to the thecal profile of the Australian form and its extremely narrow width, but in view of the absence of the sicula, positive identification is not possible. The Arctic form appears to have more closely spaced thecae than the Australian species.

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Appendix 1

Distribution of species of flattened graptolites in each section

(Species listed lowest to highest stratigraphically from each section.)

Abbott River (sections CAR and AB): 75°13'N, 95°43'W – 75°14'N, 95°44'W

CAR1: *Lobograptus progenitor*

CAR4A: *Bohemograptus bohemicus bohemicus*

CAR4D: *Pseudomonoclimacis dalejensis* (= *Pseudomonoclimacis dalejensis dalejensis* throughout the appendix)

CAR5A: *Bohemograptus bohemicus* s.l., *Pristiograptus fragmentalis*, *Sactograptus linearis*

CAR5B: *Bohemograptus bohemicus tenuis*, *Pristiograptus fragmentalis*, *Sactograptus linearis*, *Monograptus ceratus*

CAR6A: *Pseudomonoclimacis dalejensis*

AB4-99

39 m: *Pseudomonoclimacis* sp., *Sactograptus linearis*, *Bohemograptus bohemicus tenuis*

42 m: *Pseudomonoclimacis* sp., *Bohemograptus bohemicus tenuis*

47 m: *Pristiograptus* sp.

81 m: *Pristiograptus fragmentalis*, *Bohemograptus bohemicus tenuis*, *Pseudomonoclimacis dalejensis*

90 m: *Pristiograptus fragmentalis*, *Bohemograptus bohemicus tenuis*

106–109 m (talus sample): *Pristiograptus fragmentalis*, *Bohemograptus bohemicus tenuis*, *Sactograptus linearis*, ?*Linograptus* sp.

108 m: *Bohemograptus bohemicus tenuis*

110.5 m: *Sactograptus linearis*, ?*Linograptus* sp.

116 m: *Pseudomonoclimacis dalejensis*, *Sactograptus linearis*, *Bohemograptus bohemicus tenuis*, *Sactograptus linearis*, *Pseudomonoclimacis dalejensis rectus* subsp. nov.

125 m: *Sactograptus linearis*, *Bohemograptus bohemicus tenuis*

Baillie Hamilton Island: 75°44'30"N, 94°22'W

BH2, 135' (41.15 m): *Lobograptus progenitor*, *Spinograptus* sp., *Plectograptus robustus*

BH2, 235' (71.63 m): *Lobograptus progenitor*, *Plectograptus robustus*

Cape Phillips (type section of the Cape Phillips Formation): 75°37'N, 94°30'W

1470' (448 m): *Lobograptus progenitor*, *Plectograptus robustus*

1590–1610' (484.6–490.7 m): *Colonograptus colonus heathcotensis*

1850' (563.9 m): *Sactograptus linearis*, *Pristiograptus fragmentalis*

1925' (586.7 m): *Sactograptus linearis*

2075' (632.5 m): *Bohemograptus bohemicus tenuis*

2175–2200' (663.2–670.6 m): *Linograptus posthumus tenuis*, *Pseudomonoclimacis* sp.

2260' (688.8 m): *Formosograptus formosus*, *Neocolonograptus parultimus*?

2400–2450' (731.5–746.8 m): *Crinograptus operculatus*?

4430–4535' (1350.3–1382.3 m): *Neocolonograptus transgrediens*

Cape Sir John Franklin (section SJF): 76°42.5'N, 96°53'W

145 m: *Spinograptus spinosus*

147 m: *Colonograptus colonus heathcotensis*, *Neogothograptus* cf. *purus labiatus*

148 m: *Colonograptus colonus heathcotensis*, *Lobograptus progenitor*, *Neogothograptus* cf. *purus labiatus*, *Bohemograptus bohemicus* (s.l.)

149.5 m: *Bohemograptus bohemicus bohemicus*, *Lobograptus progenitor*, *Pristiograptus* sp., *Neogothograptus* cf. *purus labiatus*

151 m: *Bohemograptus bohemicus bohemicus*, *Pristiograptus* sp.

154 m: *Bohemograptus bohemicus bohemicus*, *Pristiograptus fragmentalis*?

155 m: *Bohemograptus bohemicus* (s.l.), *Pristiograptus* sp.

160 m: *Bohemograptus bohemicus* (s.l.)

163 m: *Bohemograptus bohemicus bohemicus*, *Plectograptus* sp., *Colonograptus colonus heathcotensis*?

166 m: *Pristiograptus* sp., *Bohemograptus bohemicus bohemicus*, *Plectograptus macilentus*

170 m: *Colonograptus colonus heathcotensis*, *Bohemograptus bohemicus* (s.l.), *Pristiograptus* sp.

172 m: *Colonograptus colonus heathcotensis*

174 m: *Bohemograptus bohemicus* (s.l.), *Pristiograptus* sp., *Pseudomonoclimacis dalejensis*?, ?*Plectograptus macilentus*

175 m: *Lobograptus parascanicus*

180 m: *Monograptus ceratus*

191 m: *Pseudomonoclimacis dalejensis*, *Monograptus ceratus*, *Pristiograptus fragmentalis*

195 m: *Monograptus ceratus*, *Pseudomonoclimacis dalejensis*?

211 m: *Bohemograptus bohemicus tenuis*, *Monograptus ceratus*, *Pseudomonoclimacis dalejensis*

221.5 m: *Pristiograptus fragmentalis*, *Bohemograptus bohemicus tenuis*, *Pseudomonoclimacis dalejensis*?

284 m: *Bohemograptus bohemicus tenuis*, *Pseudomonoclimacis dalejensis*?, *Bohemograptus praecornutus*

290 m: *Bohemograptus bohemicus tenuis*, *Bohemograptus garratti*

291.5 m: *Bohemograptus bohemicus tenuis*

293 m: *Bohemograptus bohemicus tenuis*

294 m: *Bohemograptus bohemicus tenuis*, *Pristiograptus* sp.

295 m: *Bohemograptus bohemicus tenuis*, *Bohemograptus praecornutus*

297 m: *Bohemograptus praecornutus*?, *Bohemograptus garratti*

298 m: *Bohemograptus praecornutus*, *Linograptus posthumus tenuis*

302 m: ?*Cucullograptus* sp.

308 m: *Neocolonograptus parultimus*?

309 m: *Neocolonograptus parultimus*?

311.5 m: *Neocolonograptus parultimus*

314 m: *Neocolonograptus ultimus*

322 m: *Neocolonograptus parultimus*?

394 m: *Neocolonograptus ultimus*, *Formosograptus formosus*

439 m: *Neocolonograptus ultimus*

599 m: *Monograptus birchensis*

SJF2: *Monograptus birchensis*

Miscellaneous GSC collections from Cape Sir John Franklin

- C198502: *Bohemograptus bohemicus bohemicus*, ?*Plectograptus macilentus*
 C198510: *Colonograptus colonus heathcotensis*
 C198514: *Lobograptus parascanicus*?
 C198515: *Bohemograptus bohemicus tenuis*
 C198519: *Monograptus birchensis*?

Grant Point (section GP): 76°04'25"N, 100°43'34"W

- 10.5 m: *Colonograptus colonus heathcotensis*, *Sactograptus varians*?
 12 m: *Neogothograptus* cf. *purus labiatus*, *Spinograptus spinosus*, *S. clathrospinosus*, *Lobograptus progenitor*
 14 m: *Spinograptus spinosus*?, ?*Plectograptus macilentus*
 15.5 m: *Plectograptus macilentus*?, *Lobograptus progenitor*
 16 m: *Pristiograptus dubius*, *Lobograptus progenitor*?
 18 m: *Pristiograptus dubius*
 20 m: *Pristiograptus dubius*, *Colonograptus colonus heathcotensis*
 22 m: *Colonograptus colonus heathcotensis*, *Bohemograptus bohemicus* (s.l.), *Bohemograptus garratti*
 27 m: *Neogothograptus* cf. *purus labiatus*
 29 m: *Linograptus posthumus posthumus*?
 36.5 m: *Monograptus ceratus*, *Pseudomonoclimacis dalejensis*?
 38 m: *Pseudomonoclimacis dalejensis*, *Sactograptus linearis*
 39.5 m: *Sactograptus linearis*, *Pseudomonoclimacis* sp., *Bohemograptus bohemicus tenuis*
 41 m: *Bohemograptus bohemicus tenuis*, *Pseudomonoclimacis dalejensis*, *Pristiograptus fragmentalis*
 45 m: *Bohemograptus bohemicus tenuis*, *Bohemograptus praecornutus*
 48 m: *Bohemograptus praecornutus*
 51 m: *Pristiograptus fragmentalis*
 52.5 m: *Pristiograptus fragmentalis*, *Pseudomonoclimacis dalejensis*
 54 m: *Neocolonograptus parultimus*?
 56 m: *Neocolonograptus parultimus*?, *Linograptus posthumus tenuis*, *Crinitograptus operculatus*?
 56.5 m: *Crinitograptus operculatus*?, *Neocolonograptus parultimus*?
 57 m: *Neocolonograptus parultimus*, *Formosograptus formosus*
 57.5 m: *Neocolonograptus ultimus*, *Monograptus* cf. *bessohaensis*
 58 m: *Crinitograptus operculatus*?, *Pristiograptus* sp.
 58.5 m: *Neocolonograptus parultimus*?
 66.5 m: *Neocolonograptus parultimus*?
 67.5 m: *Neocolonograptus parultimus*, *Formosograptus formosus*?
 70.5 m: *Formosograptus formosus*, *Neocolonograptus parultimus*?
 75 m: *Neocolonograptus ultimus*?
 80.5 m: *Neocolonograptus ultimus*, *N. branikensis*
 84 m: *Neocolonograptus ultimus*
 88 m: *Neocolonograptus ultimus*
 94 m: *Neocolonograptus ultimus*
 98 m: *Neocolonograptus transgrediens*
 105 m: *Neocolonograptus transgrediens*
 130 m: *Monograptus birchensis*
 132 m: *Monograptus birchensis*

Humphries Hill (section HH): 76°23'N, 99°24'W

- 48 m: *Lobograptus progenitor*, *Plectograptus macilentus*?
 55.5 m: *Lobograptus progenitor*, *Pristiograptus* cf. *fragmentalis*, *Colonograptus* cf. *colonus heathcotensis*, *Plectograptus macilentus*, *Spinograptus robustus*
 60 m: *Colonograptus colonus heathcotensis*, *Lobograptus progenitor*, *Sactograptus varians*
 61.5 m: *Sactograptus varians*, *Lobograptus progenitor*, *Colonograptus colonus heathcotensis*, *Spinograptus spinosus*, *Neogothograptus* cf. *purus labiatus*
 66 m: *Sactograptus varians*?, *Lobograptus progenitor*, *Spinograptus clathrospinosus*, *Plectograptus macilentus*?, *Neogothograptus* cf. *purus labiatus* n. subsp.
 72 m: *Colonograptus colonus heathcotensis*, *Lobograptus progenitor*, *Spinograptus spinosus*, *Neogothograptus thorsteinssoni* n. sp.
 76.5 m: *Lobograptus progenitor*, *Plectograptus macilentus*?, *Colonograptus colonus* (s.l.), *Pristiograptus* sp.
 81 m: *Lobograptus progenitor*
 93 m: *Bohemograptus bohemicus bohemicus*, *Pristiograptus dubius*?, *Pseudomonoclimacis dalejensis*?, *Linograptus posthumus tenuis*?
 99 m: *Bohemograptus bohemicus bohemicus*, *Linograptus posthumus tenuis*?, *Pseudomonoclimacis*? sp.
 105 m: *Pseudomonoclimacis dalejensis*?, *Lobograptus progenitor*
 112.5 m: *Pseudomonoclimacis dalejensis*?, *Spinograptus clathrospinosus*
 126 m: *Neocolonograptus ultimus*, *N. parultimus*, *N. branikensis*
 132 m: *Neocolonograptus parultimus*?
 139.5 m: *Neocolonograptus ultimus*
 148.5 m: *Neocolonograptus ultimus*, *Linograptus posthumus tenuis*
 156 m: *Neocolonograptus ultimus*, *Linograptus* sp.
 166.5 m: *Neocolonograptus ultimus*
 189 m: *Neocolonograptus transgrediens*?
 198 m: *Monograptus* cf. *birchensis*
 204 m: *Monograptus* cf. *birchensis*
 210 m: *Monograptus* cf. *birchensis*
 219 m: *Monograptus* cf. *birchensis*, *Abiesgraptus*? sp.

Irene Bay (section IB): 79°04'N, 82°14'W

- 6 m: *Formosograptus formosus*, *Neocolonograptus parultimus*
 17 m: *Formosograptus formosus*?, *Neocolonograptus parultimus*?
 19 m: *Neocolonograptus parultimus*, *Formosograptus formosus*?
 32 m: *Neocolonograptus ultimus*
 33 m: *Neocolonograptus ultimus*
 36 m: *Neocolonograptus ultimus*
 41 m: *Neocolonograptus transgrediens*?
 42.5 m: *Neocolonograptus* cf. *ultimus*
 44 m: *Neocolonograptus* cf. *transgrediens*
 55 m: *Neocolonograptus* cf. *transgrediens*
 58 m: *Neocolonograptus ultimus*
 70 m: *Neocolonograptus ultimus*
 75 m: *Neocolonograptus* cf. *transgrediens*
 102 m: *Neocolonograptus* cf. *transgrediens*
 IB-1: *Bohemograptus praecornutus*
 IB-2: *Sactograptus linearis*, *Pristiograptus* cf. *fragmentalis*

Snowblind Creek (sections SBC-1988, SB-1989, SB4-1999): 75°11'N, 93°47'W

- SBC4-5-8 m: *Lobograptus progenitor*, *Bohemograptus bohemicus bohemicus*
 SBC4-10-12 m: *Bohemograptus bohemicus bohemicus*
 SBC6: *Monograptus ceratus*, *Pseudomonoclimacis* sp.
 SBC7A: *Saetograptus linearis*, *Pristiograptus* cf. *fragmentalis*
 SBC7B: *Saetograptus linearis*
 SBC7C: *Saetograptus linearis*, *Monograptus ceratus*, *Bohemograptus bohemicus tenuis*
 SB-A-67 m (talus): *Lobograptus progenitor*, *Pristiograptus dubius* (s.l.)
 SB-D-10 m: *Pristiograptus fragmentalis*, *Bohemograptus bohemicus* (s.l.)
 SB-D-75 m: *Bohemograptus bohemicus tenuis*, *Monograptus ceratus*
 SB-F-287 m: *Pristiograptus fragmentalis*
 SB-F-300 m: *Monograptus ceratus*, *Pseudomonoclimacis dalejensis*
 SB-F-320 m: *Monograptus ceratus*
 SB-F-325 m: *Pristiograptus fragmentalis*, *Saetograptus linearis*
 SB4-1999: *Plectograptus macilentus*

Strathcona Fiord (section SF): 78°32'10"N, 82°53'20"W

- 38 m: *Neocolonograptus branikensis*?
 50 m: *Neocolonograptus ultimus*?
 80 m: *Neocolonograptus transgrediens*?
 90 m: *Neocolonograptus transgrediens*
 95 m: *Neocolonograptus transgrediens*
 100 m: *Neocolonograptus transgrediens*, *Monograptus bouceki*
 106 m: *Neocolonograptus* cf. *transgrediens*
 112 m: *Neocolonograptus transgrediens*
 113-128 m (talus): *Neocolonograptus transgrediens*
 129 m: *Neocolonograptus transgrediens*
 159 m: *Neocolonograptus transgrediens*
 165 m: *Neocolonograptus transgrediens*
 186 m: *Neocolonograptus transgrediens*
 198 m: *Neocolonograptus transgrediens*
 202 m: *Neocolonograptus transgrediens*, *Monograptus* cf. *prognatus*
 216 m: *Neocolonograptus transgrediens*
 225 m: *Neocolonograptus transgrediens*?
 231 m: *Neocolonograptus transgrediens*?
 248 m: *Neocolonograptus transgrediens*?
 264 m: *Neocolonograptus transgrediens*
 270 m: *Neocolonograptus transgrediens*
 305 m: *Neocolonograptus transgrediens*
 369 m: *Monograptus birchensis*
 394 m: *Monograptus birchensis*
 400 m: *Monograptus birchensis*
 410 m: *Monograptus birchensis*
 414 m: *Monograptus birchensis*
 428 m: *Monograptus birchensis*?
 448 m: *Monograptus birchensis*
 465 m: *Monograptus birchensis*

- 474 m: *Monograptus birchensis*
 475 m: *Monograptus birchensis*
 477 m: *Monograptus acquabilis notaequabilis* (Early Devonian)

Twilight Creek (sections TC-1988, TWW-1998, TWN-1998): 76°10'N, 99°10'W

- TC2 (156 m): *Plectograptus macilentus*, *Bohemograptus bohemicus bohemicus*, *Colonograptus colonus heathcotensis*, *Bohemograptus garratti*
 TC3A (160 m): *Bohemograptus bohemicus bohemicus*, *Lobograptus progenitor*, *Linograptus* sp., *Pristiograptus fragmentalis*?, *Plectograptus robustus*, *Spinograptus spinosus*
 TC3 (162 m): *Bohemograptus bohemicus bohemicus*, *Colonograptus colonus heathcotensis*, *Plectograptus macilentus*, *Pristiograptus* sp., *Monograptus* cf. *uncinatus*, *Bohemograptus garratti*
 TC3B (166 m): *Bohemograptus bohemicus bohemicus*, *Colonograptus colonus heathcotensis*, *Plectograptus macilentus*, *Pristiograptus fragmentalis*?, *Neogothograptus purus labiatus* n. subsp.
 TC4 (170 m): *Pristiograptus* cf. *fragmentalis*?, *Linograptus* sp., *Bohemograptus bohemicus bohemicus*, *Pseudomonoclimacis hispinosus*
 TC5 (175 m): *Monograptus ceratus*, *Bohemograptus bohemicus tenuis*, *Pristiograptus fragmentalis*
 TC6 (176 m): *Pristiograptus fragmentalis*, *Pseudomonoclimacis dalejensis*, *Saetograptus linearis*, *Bohemograptus bohemicus tenuis*?
 TC7 (177 m): *Pristiograptus fragmentalis*, *Pseudomonoclimacis dalejensis*, *Bohemograptus bohemicus tenuis*
 TC8 (178 m): *Pristiograptus fragmentalis*, *Pseudomonoclimacis dalejensis*?, *Bohemograptus bohemicus tenuis*
 TC9 (180 m): *Bohemograptus praecornutus*, *Pristiograptus* sp.
 TC10 (184 m): *Bohemograptus bohemicus tenuis*
 TC11 (190 m): *Bohemograptus bohemicus tenuis*
 TC12 (192 m): *Pseudomonoclimacis dalejensis*
 TC13 (195 m): *Formosograptus formosus*, *Monograptus* cf. *beatus*
 TC14 (198 m): *Neocolonograptus parultimus*
 TC15 (205 m): *Neocolonograptus parultimus*
 TC16 (215 m): *Neocolonograptus parultimus*
 TC17 (220 m): *Neocolonograptus ultimus*, *Monograptus bessaensis*
 TC18 (230 m): *Neocolonograptus ultimus*, *Neocolonograptus branikensis*
 TC19 (240 m): *Neocolonograptus ultimus*, *Neocolonograptus branikensis*
 TC20 (250 m): *Neocolonograptus ultimus*, *Linograptus posthumus tenuis*
 TC21 (254 m): *Neocolonograptus transgrediens*?, *Monograptus* cf. *bouceki*
 TC22 (258 m): *Neocolonograptus transgrediens*
 TC23 (262 m): *Neocolonograptus transgrediens*
 TC24 (270 m): *Neocolonograptus transgrediens*
 TC25 (275 m): *Neocolonograptus transgrediens*, *Linograptus* sp.
 TC26 (280 m): *Neocolonograptus transgrediens*, *Linograptus* sp.
 TC27 (290 m): *Neocolonograptus transgrediens*, *Monograptus bouceki*, *Linograptus posthumus tenuis*

TC28 (300 m): *Neocolonograptus transgrediens*, *Linograptus posthumus tenuis*

TC29 (350 m): *Neocolonograptus transgrediens*, *Linograptus posthumus tenuis*

TC30 (370 m): *Neocolonograptus transgrediens*

TC32 (400 m): *Neocolonograptus transgrediens*?

TC33 (440 m): *Neocolonograptus transgrediens*

TC34 (490 m): *Neocolonograptus transgrediens*

TC35 (520 m): *Monograptus birchensis*

TC36 (530 m): *Monograptus birchensis*

TC37 (540 m): *Monograptus birchensis*

TC38 (550 m): *Monograptus uniformis* (Early Devonian)

TW-98, 138–148 m: *Colonograptus colonus heathcotensis*

TWW 15.1 m: *Lobograptus progenitor*, *Colonograptus colonus heathcotensis*, *Neogothograptus* sp., *Linograptus posthumus posthumus*?

TWW 16.5 m: *Lobograptus progenitor*

TWW 18 m: *Lobograptus progenitor*, *Pristiograptus* sp.

TWW 19.5 m: *Lobograptus progenitor*, *Neogothograptus* sp., *Bohemograptus bohemicus bohemicus*

TWW 22.5 m: *Neogothograptus* sp., *Pristiograptus fragmentalis*?

TWW 23.8 m: *Pristiograptus fragmentalis*?, *Colonograptus colonus heathcotensis*, *Linograptus* sp., *Plectograptus macilentus*?

TWW 25 m: *Pristiograptus fragmentalis*, *Bohemograptus bohemicus bohemicus*, *Linograptus* sp.

TWW 26.5 m: *Bohemograptus bohemicus bohemicus*

TWW 30 m: *Bohemograptus bohemicus bohemicus*, *Plectograptus macilentus*?, *Linograptus* sp., *Pristiograptus* sp.

TWW 32.5 m: *Bohemograptus bohemicus tenuis*?, *Colonograptus colonus heathcotensis*

TWW 35 m: *Colonograptus colonus heathcotensis*, *Neogothograptus* sp.

TWW 38.5 m: *Colonograptus colonus heathcotensis*, *Bohemograptus bohemicus* (s.l.)

TWW 47.5 m: *Monograptus ceratus*?

TWW 52 m: *Monograptus ceratus*, *Pristiograptus* sp.

TWN 0 m: *Monograptus ceratus*, *Bohemograptus bohemicus tenuis*, *Saetograptus linearis*, *Pristiograptus* cf. *fragmentalis*

TWN 1.5 m: *Monograptus ceratus*, *Bohemograptus bohemicus tenuis*, *Saetograptus linearis*, *Pristiograptus* sp.

TWN 4.5 m: *Pseudomonoclimacis dalejensis*, *Pristiograptus* sp.

TWN 5.5 m: *Bohemograptus bohemicus tenuis*, *Pristiograptus* sp.

TWN 7 m: *Bohemograptus bohemicus tenuis*, *Pseudomonoclimacis dalejensis*

TWN 9 m: *Bohemograptus bohemicus tenuis*?

TWN 12.5 m: *Bohemograptus bohemicus tenuis*, *Formosograptus formosus*?

TWN 18 m: *Bohemograptus bohemicus tenuis*

TWN 22 m: *Pristiograptus* sp.

TWN 23.5 m: *Neocolonograptus parultimus*?

TWN 24 m: *Neocolonograptus parultimus*

TWN 30 m: *Neocolonograptus parultimus*?

TWN 32 m: *Neocolonograptus parultimus*

TWN 35 m (talus; same stratigraphic level as TC 220 m): *Neocolonograptus ultimus*, *N. branikensis*, *Formosograptus formosus*, *Monograptus bessobaensis*

Miscellaneous collections

Cape Lyons, Devon Island: 76°24'N, 90°34'W

C198453: *Bohemograptus praecornutus*

C198455: *Neocolonograptus parultimus*

C198693: *Bohemograptus praecornutus*

C198695: *Pseudomonoclimacis dalejensis*?

C198696: *Pseudomonoclimacis* sp., ?*Cucullograptus* sp.

C198697: *Neocolonograptus parultimus*

C198698: *Neocolonograptus parultimus*

C198699: *Neocolonograptus ultimus*, *N. transgrediens*

Colin Archer Peninsula, Devon Island: 76°22'11"N, 91°03'43"W

C198740: *Monograptus birchensis*

C198741: *Monograptus birchensis*

Cut Through Creek, Bathurst Island: 76°09'N, 98°58'W

C207056: *Neocolonograptus transgrediens*

C207161: *Lobograptus progenitor*

Eidsbotn River, Devon Island: 76°21'N, 91°45'W

C146440: *Neocolonograptus transgrediens*, *N. ultimus*

C146441: *Neocolonograptus transgrediens*

C146443: *Monograptus* cf. *birchensis*

C146446: *Monograptus birchensis*, *Monograptus microdon curvatus* n. subsp.

Middle Island, Melville Island (section MMI): 75°52'N, 111°54'W

122.5 m: *Pristiograptus* cf. *fragmentalis*, *Bohemograptus bohemicus bohemicus*, *Lobograptus progenitor*

Moses Robinson River, Bathurst Island: 76°03'N, 97°48'W

C207017: *Neocolonograptus parultimus*

C207019: *Monograptus birchensis*?

C207032: *Neocolonograptus parultimus*, *Formosograptus formosus*

C207033: *Neocolonograptus parultimus*?, *Formosograptus formosus*

C207035: *Neocolonograptus transgrediens*

Walker River, Bathurst Island: 75°58'N, 98°02'W

C199111: *Bohemograptus bohemicus* (s.l.), *Bohemograptus*? *helicoides*

Judge Daly Promontory, Northeastern Ellesmere Island: 80°53'N, 68°53'W

de Freitas collection 5-8: *Pseudomonoclimacis norfordi*?

de Freitas collection 9-3: *Pseudomonoclimacis norfordi*, *Formosograptus formosus*

Appendix 2

Distribution of isolated, three-dimensionally preserved graptolites in each section

Abbott River (section AB2-1999): 75°13'N, 95°43'W – 75°14'N, 95°44'W

- 19 m: *Lobograptus* sp., *Neogothograptus* sp.
 20.5 m: *Neogothograptus purus labiatus* n. sp.
 21 m: *Neogothograptus* sp.?, *Crinograptus operculatus*, ?*Lobograptus* sp., *Pristiograptus* sp.
 22 m: *Crinograptus operculatus*, *Neogothograptus alatifomis* n. sp., *Pristiograptus* sp.
 23 m: *Crinograptus* cf. *operculatus*, *Neogothograptus alatifomis* n. sp., *Colonograptus colonus heathcotensis*?, dendroid
 25.5 m: *Neogothograptus thorsteinssoni* n. sp.
 30 m: *Colonograptus colonus heathcotensis*, *Crinograptus* cf. *operculatus*
 31 m: *Neogothograptus thorsteinssoni* n. sp.
 48 m: ?*Lobograptus* sp., *Pristiograptus* sp.
 52 m: *Pristiograptus* sp., *Spinograptus clathrospinosus*
 58.5 m: *Holoretolites manckoides*, *Lobograptus* spp., *Lobograptus scanicus*, ?*Pseudomonoclimacis* sp. *Pseudomonoclimacis dalejensis*, *Pristiograptus fragmentalis*, dendroid indet.
 61 m: *Lobograptus scanicus*, *Lobograptus* sp.
 62 m: *Lobograptus* sp., *Pseudomonoclimacis dalejensis*
 63 m: *Lobograptus scanicus*, *Pseudomonoclimacis dalejensis*, *Lobograptus* sp., ?*Monograptus ceratus*
 74 m: *Pristiograptus* sp.
 82 m: *Pseudomonoclimacis dalejensis*, ?*Lobograptus* sp., ?*Lobograptus scanicus*
 94 m: *Pristiograptus fragmentalis*

Baillie Hamilton Island (section BH-1991, BH2-1998): 75°45'N, 94°21.6'W

- BH-15 m: *Pristiograptus* cf. *fragmentalis*
 BH-43.5 m: *Colonograptus* ex gr. *colonus*
 BH-57.6 m: *Plectograptus macilentus*, *Lobograptus progenitor*, *Pseudomonoclimacis dalejensis*?, *Saetograptus* sp., *Neogothograptus purus labiatus* n. subsp., *Neogothograptus thorsteinssoni* n. sp., *Spinograptus robustus*
 BH-82.5 m: *Neogothograptus purus labiatus* n. sp., *Neogothograptus thorsteinssoni* n. sp., *Colonograptus colonus heathcotensis*, eurypterid fragments
 BH-86 m (= 145 m of BH2-1991): *Pseudomonoclimacis dalejensis*, *Saetograptus varians*?, *Neogothograptus melchimi* n. sp.
 BH2-65 m (upper Homerian): *Pristiograptus* sp., *Papiliograptus* sp.
 BH32-71 m: *Pristiograptus jaegeri*?
 BH2-73 m: "Gothograptus" sp., eurypterid fragments (?)
 BH2-90 m: *Neogothograptus* sp., *Pristiograptus* sp.
 BH-92 m: *Pristiograptus fragmentalis*, *Neogothograptus thorsteinssoni* n. sp., ?*Spinograptus* sp., *Plectograptus*? sp.
 BH2-108 m: *Saetograptus* sp., *Pristiograptus* sp., ?*Neogothograptus* sp., ?*Lobograptus* sp.
 BH2-116 m: *Colonograptus colonus heathcotensis*

- BH2-118 m: *Colonograptus colonus heathcotensis*, *Neogothograptus thorsteinssoni* n. sp.
 BH2-128 m: *Colonograptus colonus heathcotensis*, *Neogothograptus* sp.
 BH2-135 m: *Pristiograptus* sp., *Bohemograptus* sp., *Neogothograptus thorsteinssoni* n. sp., *Plectograptus*? sp.
 BH2-137 m: *Neogothograptus thorsteinssoni* n. sp.
 BH2-140 m: *Neogothograptus alatifomis* n. sp., *Pristiograptus* sp., *Plectograptus*? sp., dendroid
 BH2-145 m: *Pristiograptus* sp., *Neogothograptus purus labiatus* n. subsp., *Neogothograptus alatifomis* n. sp., *Plectograptus*? sp.
 BH2-146.5 m: *Colonograptus colonus heathcotensis*, *Pristiograptus* sp., *Neogothograptus alatifomis* sp. nov., *Plectograptus macilentus*, dendroid
 BH2-147 m: *Colonograptus colonus heathcotensis*, *Pristiograptus* sp., *Neogothograptus alatifomis* n. sp.
 BH2-149 m: *Colonograptus colonus heathcotensis*, *Pristiograptus* sp., *Bohemograptus* sp., *Neogothograptus purus labiatus* n. subsp.
 BH2-153 m: *Neogothograptus purus labiatus* n. subsp., *Pristiograptus* sp., *Bohemograptus* sp., *Pseudomonoclimacis dalejensis*, *Plectograptus macilentus*?, dendroid
 BH2-180 m: *Bohemograptus bohemicus tenuis*, *Pristiograptus* sp., ?*Plectograptus* sp.
 BH2-191 m: *Bohemograptus* sp., ?*Lobograptus* sp., dendroid
 BH2-198 m: *Pseudomonoclimacis dalejensis*, *Pristiograptus* sp., ?*Lobograptus* sp., *Neogothograptus* sp., *Lobograptus* cf. *heklemishevi*
 BH2-203 m: *Pristiograptus* sp.
 BH2-206 m: *Pseudomonoclimacis dalejensis*, *Pristiograptus dubius* (s.l.)
 BH2-209 m: *Pristiograptus dubius labiatus*?, ?*Lobograptus* sp.
 BH2-365 m: *Pseudomonoclimacis dalejensis*, ?*Lobograptus* sp., *Neogothograptus*? sp.
 BH2-389 m: *Pseudomonoclimacis dalejensis*, ?*Lobograptus* sp.
 BH2-492 m: *Neocolonograptus ultimus*, *N. parultimus*

Cape Manning area, Cornwallis Island: 75°26.6'N, 94°09'W

- MCM-90, MCM-91: *Plectograptus macilentus*, *Neogothograptus melchimi* n. sp., *Pseudomonoclimacis* cf. *dalejensis*, *Bohemograptus bohemicus tenuis*, *Lobograptus*? sp.

Cape Sir John Franklin (section SJF): 76°42.5'N, 96°53'W

- 145 m: *Spinograptus clathrospinosus*, *Spinograptus spinosus*, *Neogothograptus thorsteinssoni* n. sp.
 155 m: *Pristiograptus* sp., *Spinograptus quadratus*, *Spinograptus clathrospinosus*

Grant Point (section GP): 76°04'25"N, 100°43'34"W

- 12 m: *Neogothograptus* sp., *Spinograptus spinosus*, *Neogothograptus thorsteinssoni* n. sp.
 27 m: *Neogothograptus purus labiatus* n. subsp.

Rookery Creek (section RC-01; RC1-02):
75°21.96'N, 95°45.13'W

- 17.5 m: *Pseudomonoclimacis dalejensis dalejensis*, *Pristiograptus fragmentalis*, *Pristiograptus fragmentalis*?, *Bohemograptus bohemicus* (s.l.)
18.5 m: ?*Holoretiolites* sp., *Pristiograptus fragmentalis*?, *Bohemograptus* sp.
19.5 m: *Pseudomonoclimacis dalejensis dalejensis*, *Pristiograptus fragmentalis*?
20 m: ?*Holoretiolites* sp.
21 m: *Holoretiolites atrabecularis*, *Pseudomonoclimacis dalejensis dalejensis*, *Lobograptus scanicus*, *Lobograptus progenitor*, ?*Lobograptus* sp., *Pristiograptus fragmentalis*
22 m: *Holoretiolites manckoides*, *Holoretiolites atrabecularis*, *Lobograptus progenitor*, ?*Lobograptus* sp., *Pseudomonoclimacis dalejensis dalejensis*, *Pseudomonoclimacis*? *brevicucullus* n. sp., ?*Prolinograptus packhami*

Snowblind Creek (sections SBC-1988, SB-1990, SB-1997, SB2-1999): 75°11'N, 93°47'W

SBC-88

- 4-7 m: *Plectograptus macilentus*, *Neogothograptus purus labiatus* n. subsp., *Lobograptus progenitor*, *Bohemograptus* sp., dendroid
4-15 m: *Pseudomonoclimacis dalejensis*, *Pristiograptus* sp., ?*Lobograptus* sp., eurypterid fragment?
7A: *Monograptus ceratus*, *Pristiograptus jaegeri*?, *Bohemograptus bohemicus* (s.l.), dendroid
8E: *Colonograptus colonus heathcotensis*, *Pristiograptus*? sp., *Neogothograptus purus labiatus* n. subsp., *Spinograptus clathrospinosus*
8F: *Pristiograptus* sp., *Spinograptus clathrospinosus*
8H: *Neogothograptus* sp., *Pseudomonoclimacis dalejensis*, ?*Lobograptus* sp.

SB-90

- B-2 m: *Neogothograptus purus labiatus* n. sp., *Pseudomonoclimacis*? sp.
B-5 m: *Colonograptus colonus heathcotensis*, *Pseudomonoclimacis* sp., *Pseudomonoclimacis dalejensis*, *Bohemograptus bohemicus* (s.l.), *Neogothograptus purus labiatus* n. subsp.
B-27 m: *Lobograptus* sp., *Pseudomonoclimacis dalejensis*, dendroid
D-10 m: *Pseudomonoclimacis dalejensis*, *Pristiograptus* sp., *Monograptus ceratus*, *Saetograptus* sp., dendroid
D-75 m: *Saetograptus linearis*, *Pristiograptus fragmentalis*, *Pseudomonoclimacis dalejensis*, *Monograptus* cf. *uncinatus*

SB-97

- A (-)2 m: *Neogothograptus purus labiatus* n. subsp.

A 0.5 m: *Neogothograptus purus labiatus* n. subsp.

A 1.5 m: *Neogothograptus melchini* n. sp., *Pseudomonoclimacis dalejensis*, *Pristiograptus dubius*?, *Saetograptus colonus heathcotensis*

A 2 m: *Pseudomonoclimacis dalejensis*?, *Neogothograptus melchini* n. sp., *Saetograptus colonus heathcotensis*, dendroid

A 3 m: *Pseudomonoclimacis dalejensis*?

A 4.5 m: *Pseudomonoclimacis dalejensis*?, *Neogothograptus purus labiatus* n. subsp., *Pristiograptus* sp., *Bohemograptus* sp.

A 5 m: *Pseudomonoclimacis dalejensis*?, *Neogothograptus purus labiatus* n. subsp., *Lobograptus* cf. *progenitor*, *Pristiograptus* sp.

A 5.5 m: *Pseudomonoclimacis dalejensis*

A 14 m: *Pristiograptus fragmentalis*, *Pseudomonoclimacis dalejensis*, eurypterid fragments?

A 15 m: *Lobograptus* cf. *progenitor*, *Pseudomonoclimacis dalejensis rectus* n. subsp., dendroid

A 16 m: *Pseudomonoclimacis dalejensis*, *Bohemograptus* sp., *Plectograptus macilentus*, *Neogothograptus* sp.

C 3 m: *Pristiograptus fragmentalis*?, *Pseudomonoclimacis dalejensis*

D-1: *Pristiograptus fragmentalis*?, *Pseudomonoclimacis dalejensis rectus* n. subsp.

D-2: *Pristiograptus fragmentalis*?, *Pseudomonoclimacis dalejensis*, *Bohemograptus bohemicus tenuis*?, *Saetograptus linearis*, *Lobograptus parascanicus*?

SB2-99

7 m: *Pseudomonoclimacis hispinosus*, *Pristiograptus* sp., "Pristiograptus" sp.

44 m: *Pseudomonoclimacis hispinosus*?

TC312B, Northeastern Cornwallis Island, loose sample: 75°26.5'N, 94°18'W

Neogothograptus thorsteinssoni n. sp., *Lobograptus progenitor*, *Saetograptus varians*

C11445 (Unnamed creek, southeastern Baillie Hamilton Island): 75°48.7'N, 94°23'W

Monograptus birchensis

C11472 (Abandon Bay, north-eastern Cornwallis Island): 75°28'N, 94°05'W

Neocolonograptus transgrediens

C61679 (TC711C), Grinnell Peninsula, Devon Island, loose sample: 76°42'N, 96°53'W

Neogothograptus alatifomis n. sp.

Plates 1–46

Plate 1

Figs. 1, 8. *Dictyonema* sp.

- 1, 8. GSC 125947, SBC 8E, disto-lateral view and profile.

Figs. 2, 13. *Acanthograptus?* sp.

- 2, 13. GSC 125948, SB97 A 4.5 m, disto-lateral view and profile.

Figs. 3, 4. *Thallograptus?* sp. 1.

- 3, 4. GSC 125949, SB97 A 4.5 m, stereopair and distal view.

Figs. 5, 10. *Thallograptus?* sp. 2.

- 5, 10. GSC 125950, BH2-98, 146.5 m, profile and distal view of thecae.

Figs. 6, 14. *Dendroid* indet.

- 6, 14. GSC 125951, SB97 A 4.5 m, stereopair and disto-lateral view.

Fig. 7. *Epigraptus?* sp.

7. GSC 125952, SB97 A 4.5 m.

Fig. 9. *Thallograptus?* sp. 3

9. GSC 125953, SB97 D#1, stereopair.

Figs. 11, 12. *Dendrograptus* sp.

- 11, 12. GSC 125954, BH2-98 71 m, profile and disto-lateral view.

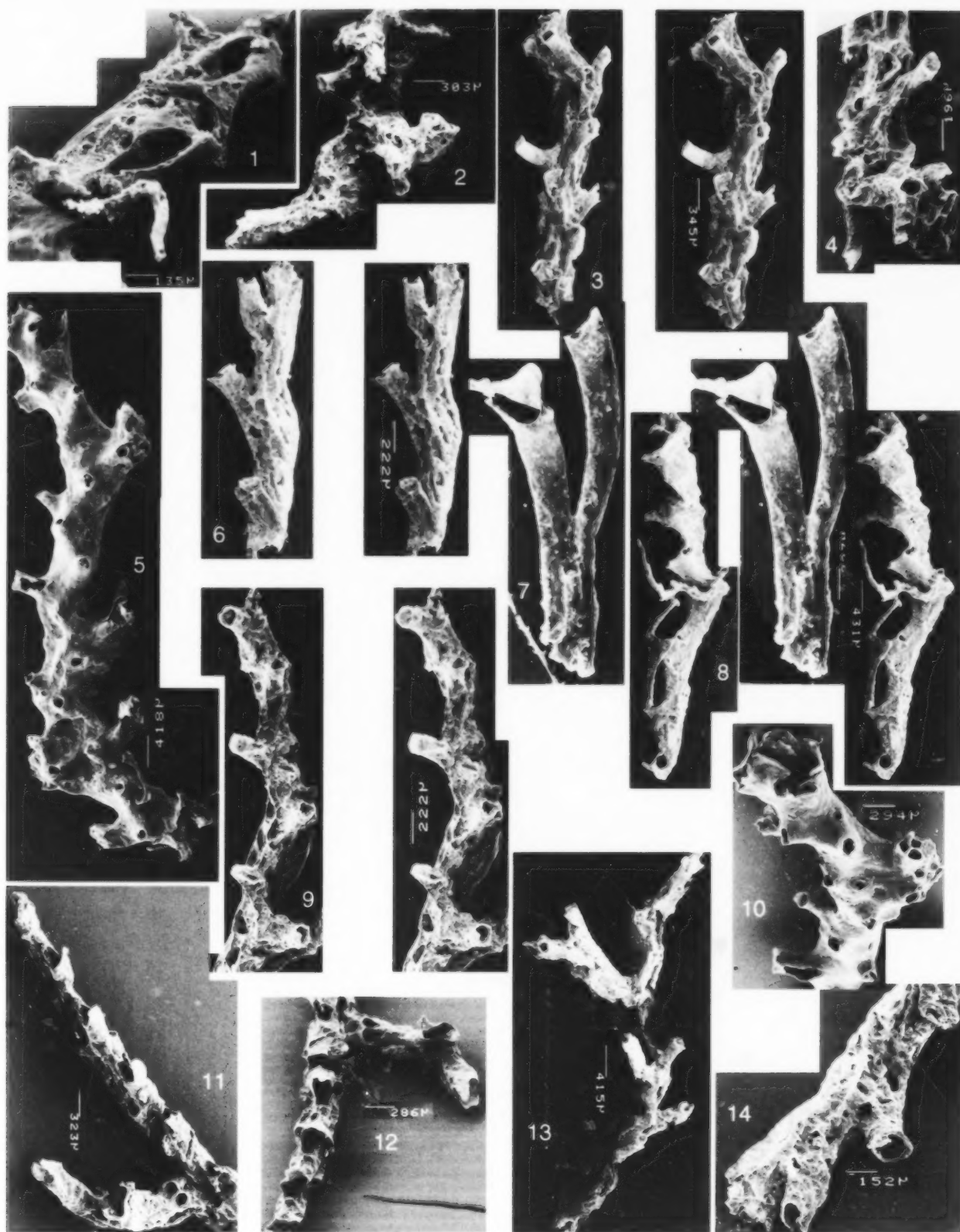


Plate 2

Figs. 1-7. ?*Prolinograptus packhami* Rickards and Wright, 1997, RC1-01, 22 m.

- 1, 2. GSC 125955, stereopair and tilted view of Fig. 1, to show thecal aperture.
- 3. GSC 125956, stereopair.
- 4, 5. GSC 125957, enlargement of theca, and tilted view of Fig. 4.
- 6, 7. GSC 125958, stereopair, and tilted view of Fig. 6 to show thecal aperture.

Figs. 8-14. *Thallograptus* sp. 4, RC1-01, 22 m.

- 8. GSC 125959, complete specimen.
- 9, 11. GSC 125960, complete specimen and enlargement of distal end.
- 10. GSC 125961, fragment enlarged to show thecae.
- 12. GSC 125962, stereopair of fragment with several branches.
- 13, 14. GSC 125963, fragment and distal end enlargement showing thecae.

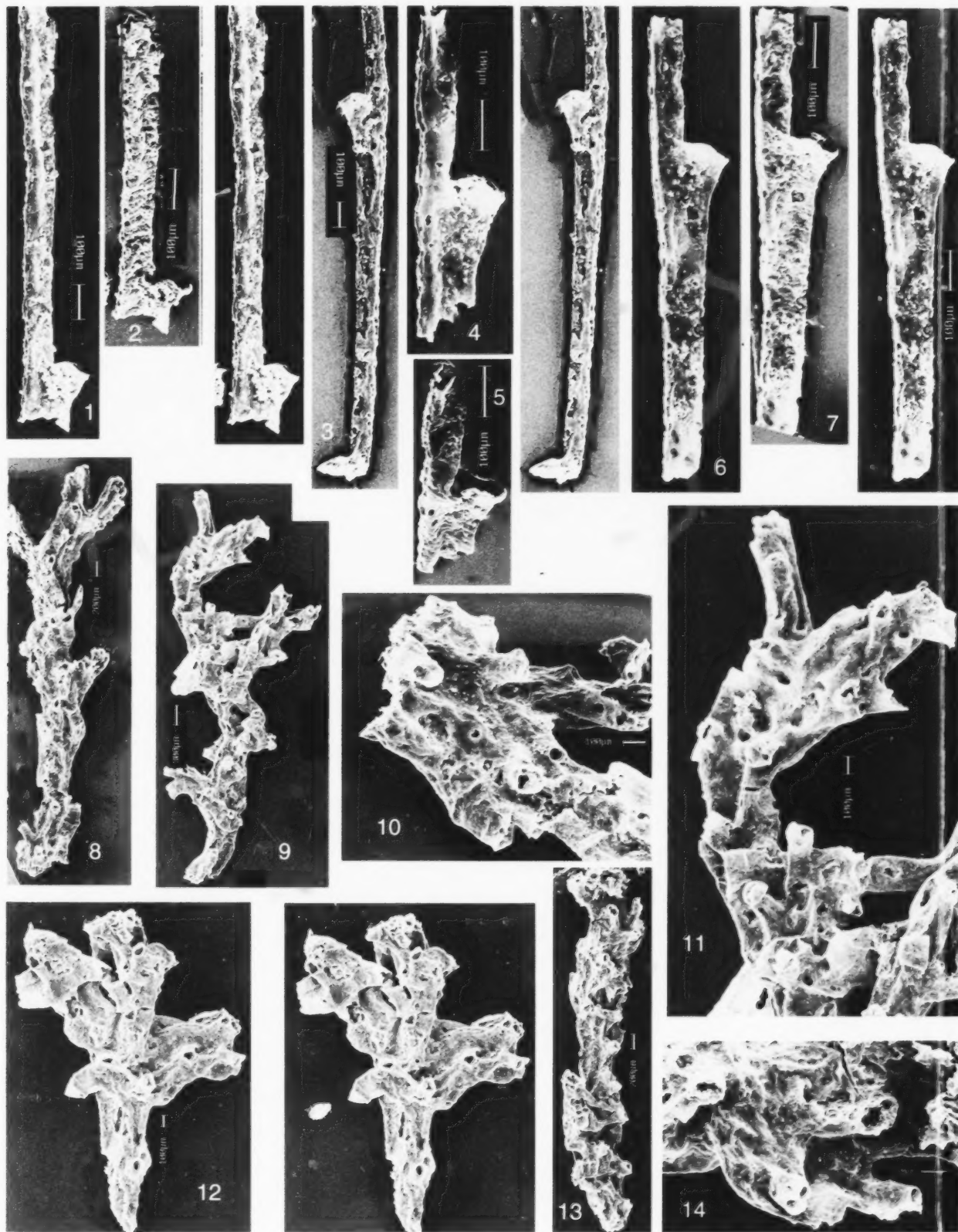


Plate 3

Figs. 1–12. *Neogothograptus purus labiatus* n. subsp.

1, 3–12. Holotype GSC 125964, BH-57.6 m.

1. Stereopair of oblique view showing arrangement of lists and thickening of lips.
3. Outside view of ancora umbrella.
4. Inside view of ancora umbrella with short virgella fragment (arrow).
5. Thin list on pleural list in distal part of rhabdosome.
6. Enlargement of Fig. 5.
7. Thin list on pleural list in distal part of rhabdosome.
8. Stereopair of ventral view of rhabdosome and theca 1.
9. Stereopair of reverse view of rhabdosome.
10. Stereopair of ventral view of rhabdosome and theca 2.
11. Enlargement of lip with small labia.
12. Inside view of th 3¹.

2. Paratype GSC 125965, BH-57.6 m, stereopair of obverse view of rhabdosome.

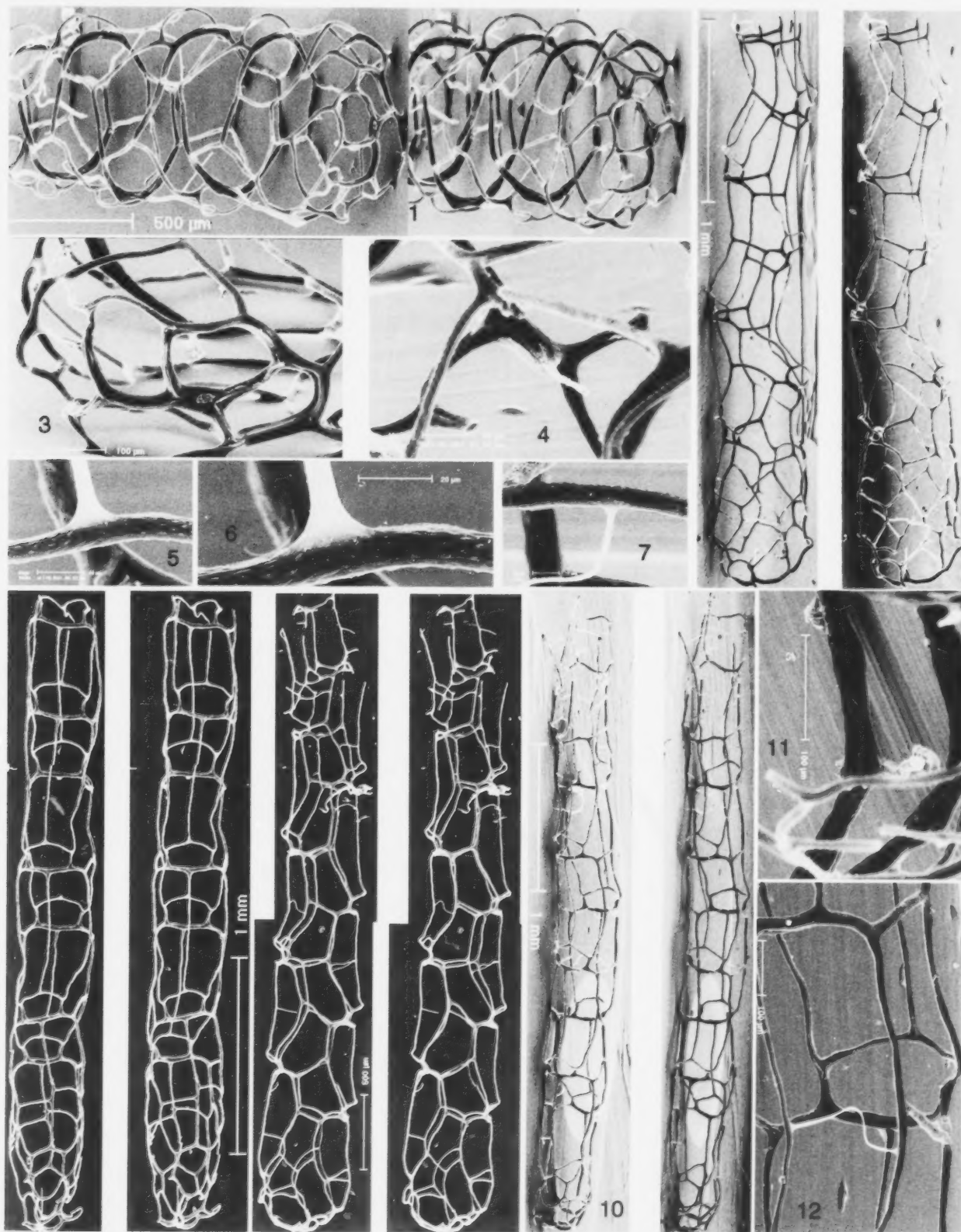


Plate 4

Figs. 1–11. *Neogothograptus purus labiatus* n. subsp., BH-57.6 m.

1, 6, 8, 9. Paratype GSC 125966.

1. Outside view of ancora umbrella.
6. Enlargement of thecal aperture with strong thecal labia.
8. Ventro-lateral view of proximal end and three thecae.
9. Stereopair of proximal region showing obverse side of rhabdosome with a few reticular lists on ancora sleeve.

3–5, 7. Paratype GSC 125967.

3. Ventro-lateral view of fragment of specimen containing two pairs of thecae with distinctive thecal lip labia.
4. Stereopair of ventro-lateral view.
5. Stereopair of lateral view.
7. Enlargement of thecal aperture with strong lip labia.

2, 10, 11. Paratype GSC 125968.

2. Oblique view of ancora umbrella with one thin list of outer ancora.
10. Ventro-lateral view of rhabdosome with three pairs of thecae and thin lists developed on ventral wall.
11. Stereopair of obverse side of proximal end of rhabdosome showing reticular lists on ancora sleeve.

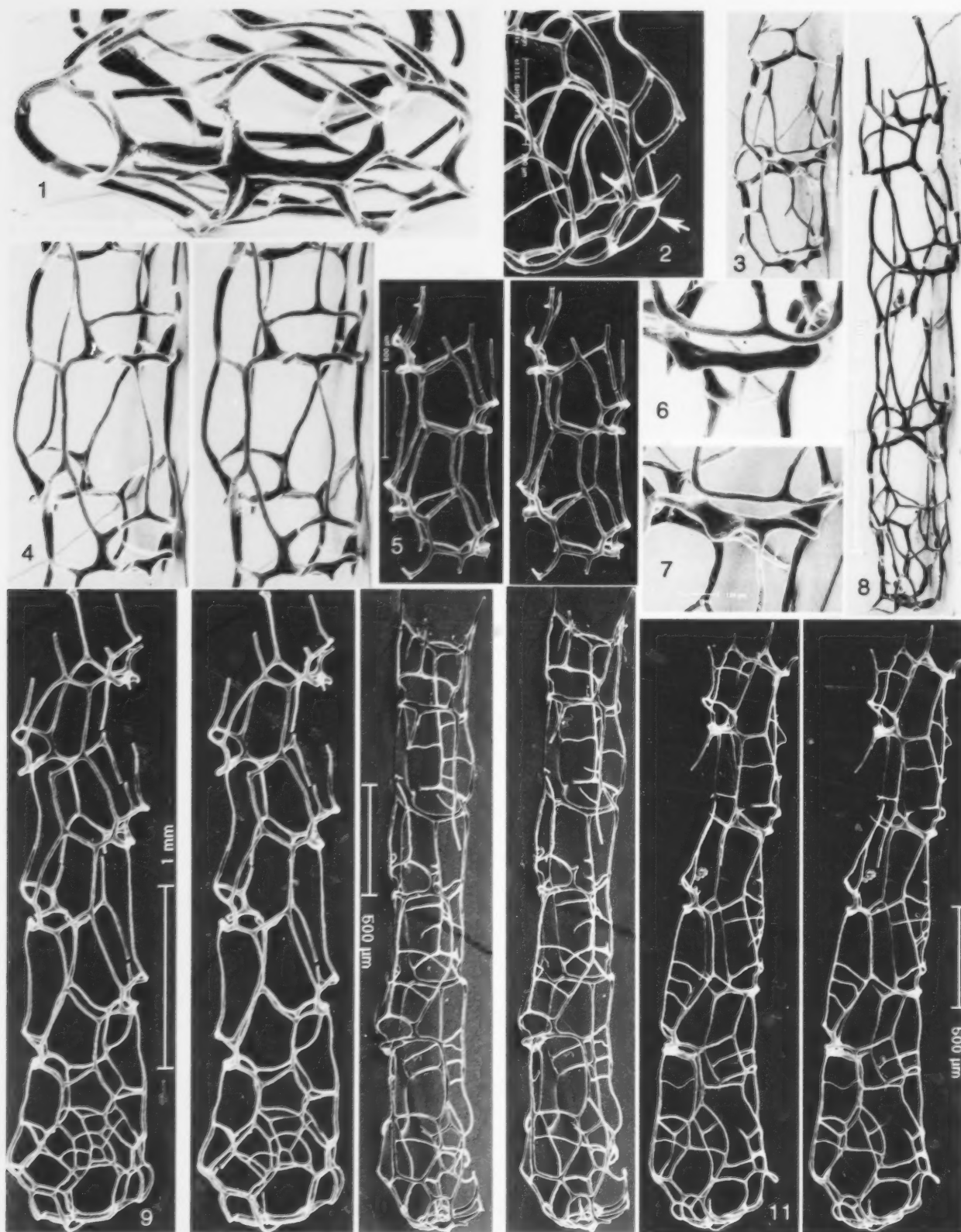


Plate 5

Figs. 1–9. *Neogothograptus purus labiatus* n. subsp., BH 57.6 m (st. 176).

1, 2, 4–6. Paratype GSC 125969, immature specimens with two pairs of thecae developed.

1. Stereopair of proximal obverse side of rhabdosome showing few reticular lists on ancora sleeve.
2. Stereopair of oblique view of proximal end of rhabdosome showing outside of ancora umbrella.
4. Ventral view of two thecae with distinctive labia on lips.
5. Inside, oblique view of ancora sleeve and ancora umbrella.
6. Outside view of ancora.

3, 7–9. Paratype GSC 125970.

3. Stereopair of oblique view of proximal end of rhabdosome showing outside of ancora umbrella.
7. Enlargement of proximal end of rhabdosome.
8. Lateral view of specimen.
9. Stereopair of reverse side of rhabdosome with four thecae.

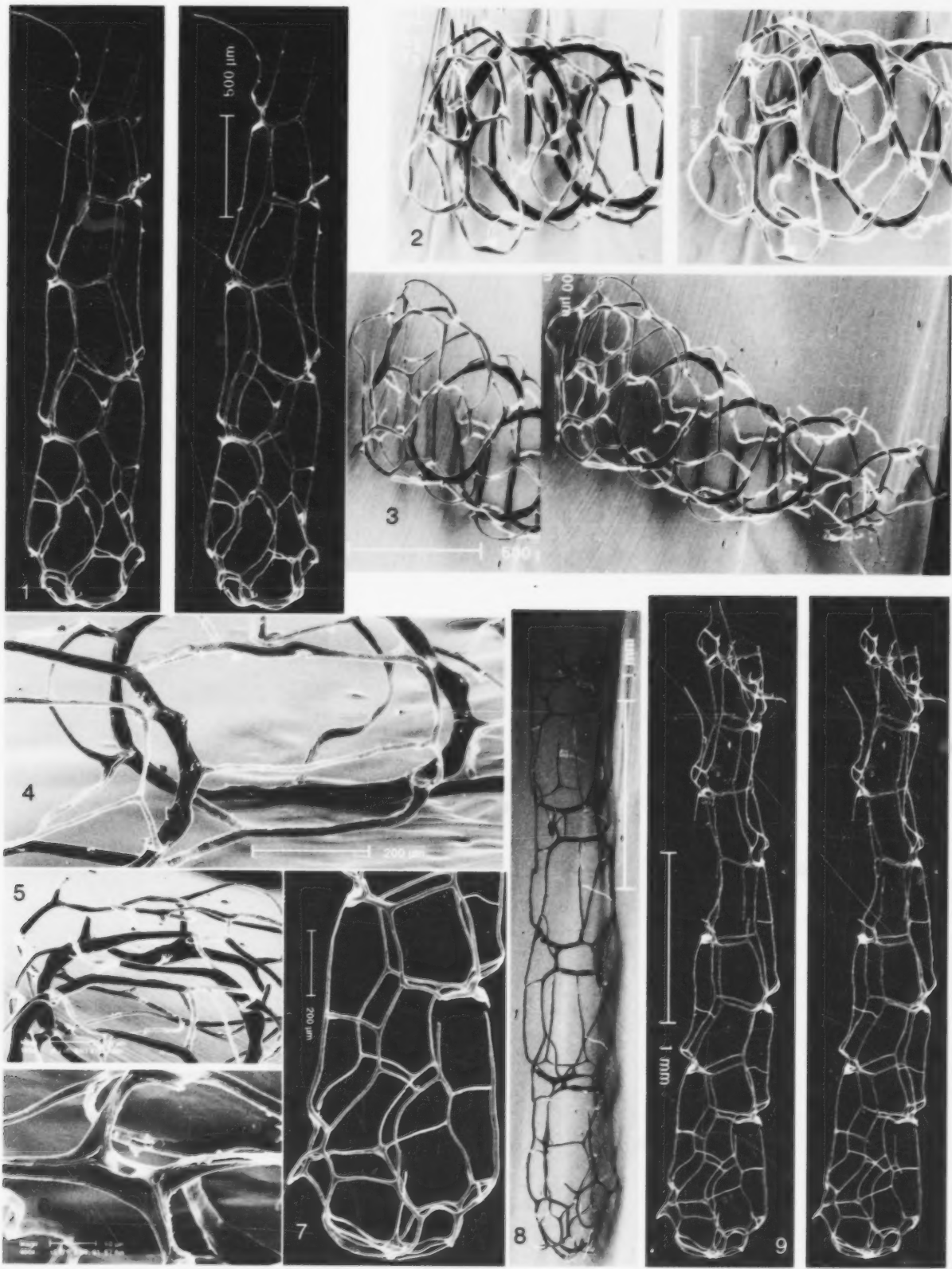


Plate 6

Figs. 1–10. *Neogothograptus purus labiatus* n. subsp., SBC 8E (st. 120).

1, 3–5. Paratype GSC 125971.

1. Stereopair of fragment of rhabdosome with two pairs of thecae.
3. Stereopair of ventro-lateral view of proximal part of rhabdosome showing strong lists, ancora umbrella, and short virgella.
4. View of ancora from inside.
5. View of ancora from outside.

2. Paratype GSC 125972, stereopair of oblique view of proximal part of rhabdosome.

6, 9, 10. Paratype GSC125973.

6. Enlargement of appendix.
9. Stereopair of thecae.
10. Distal part of rhabdosome showing strong lists and appendix.

7, 8. Paratype GSC 125974.

7. Proximal part of rhabdosome with four thecae.
8. Outside view of ancora umbrella with unusual thickenings.

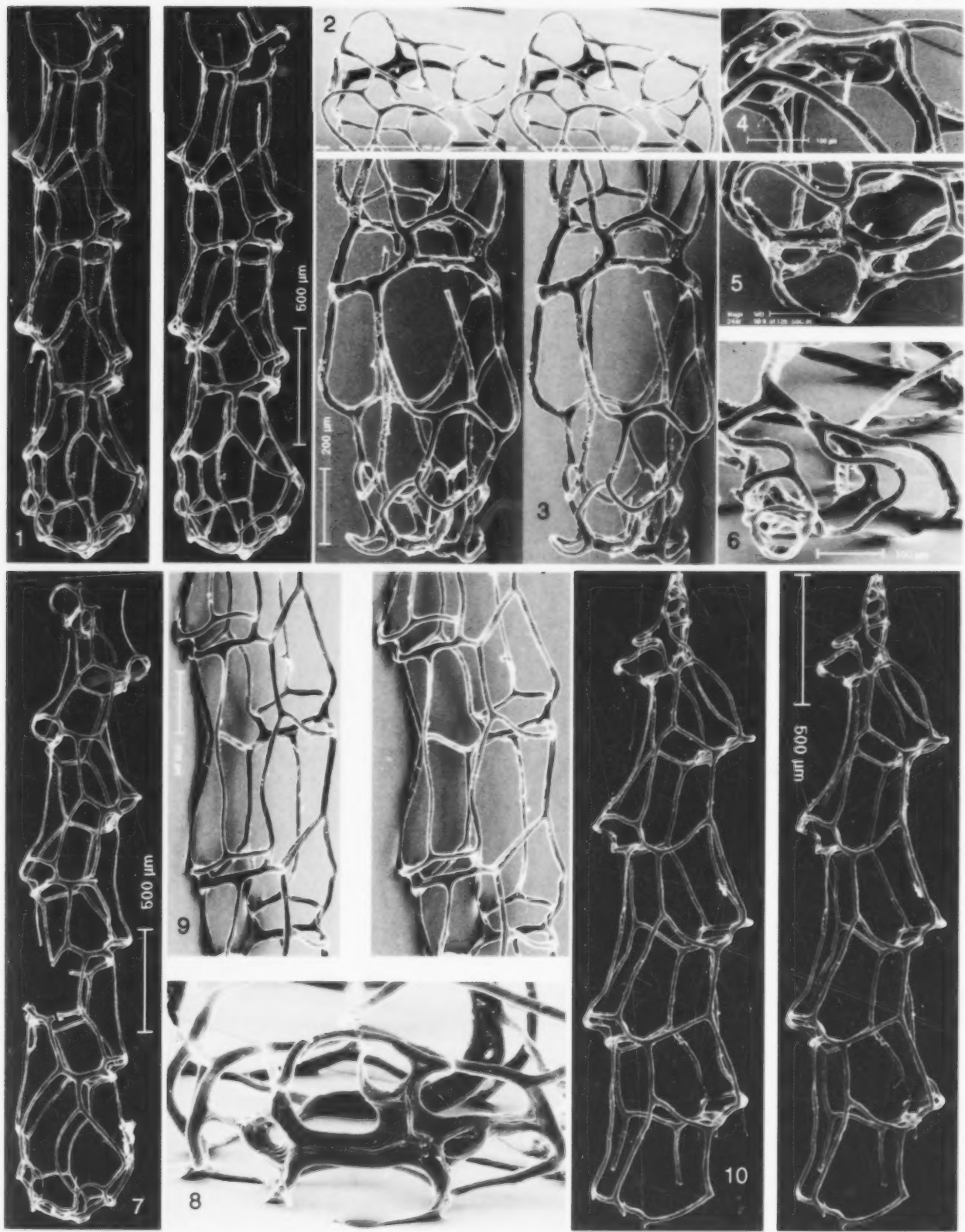


Plate 7

Figs. 1, 2, 5, 7, 8. *Neogothograptus thorsteinssoni* n. sp. GP-12 m, Paratype GSC 125975.

1. Oblique view from distal part of fragment of rhabdosome showing very thick lips.
2. Enlargement of th 1¹ with abnormal genicular hood.
5. Stereopair of ventral side of specimen with ventral orifices partly closed by reticular lists.
7. Enlargement of underside of thickened lip of above specimen.
8. Stereopair of lateral side.

Figs. 3, 4, 6, 9, 10. *Neogothograptus purus labiatus* n. subsp. SBC 8E, Paratype GSC 125976.

3. Enlargement of ventral view of thecae.
4. Enlargement of appendix with strong bandages.
6. Inside view of ancora with short virgella.
9. Ventro-lateral view of specimen.
10. Stereopair of reverse view of specimen.

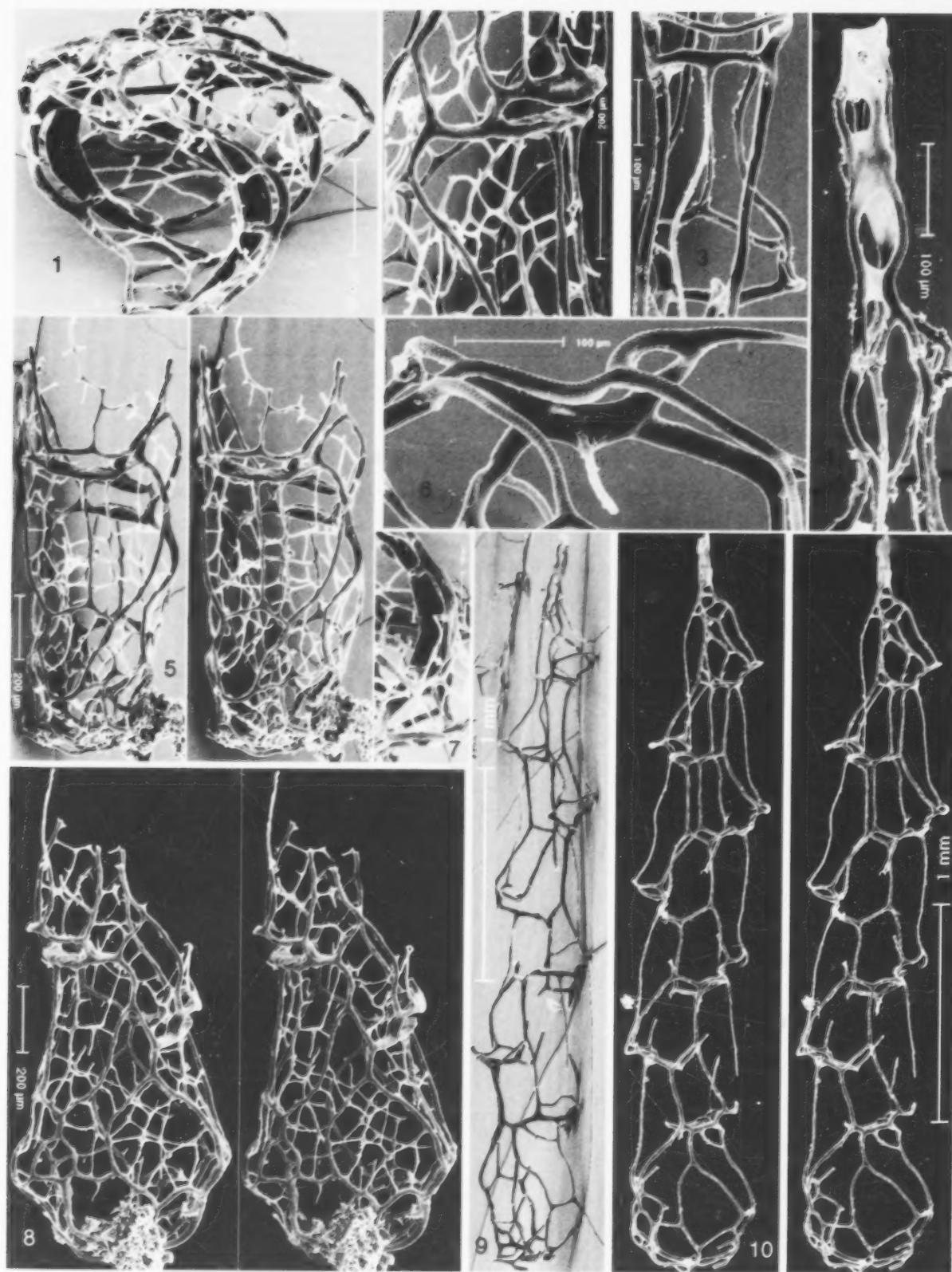


Plate 8

Figs. 1–11. *Neogothograptus thorsteinssoni* n. sp.

1, 2, 4–11. Paratype GSC 125977, AB2-99, 25.5 m.

1. Stereopair of reverse view of specimen with three pairs of thecae.
2. Stereopair of ventral view of th 1¹ wall.
4. Oblique proximal view of rhabdosome showing densely reticulated outer ancora.
5. Proximal view of strong lip.
6. Inside view of thick ancora with very short virgella.
7. Enlargement of proximal view into thecal orifice.
8. Outside view of outer ancora.
9. Enlargement of lateral view of proximal end.
10. Stereopair of oblique view of ancora sleeve wall and ventral wall with three thecae.
11. Stereopair of proximal-ventral view of th 1² wall showing orifice closed by reticulum.

3. Paratype GSC 125978, BH2, 57.6, mature rhabdosome with six pairs of thecae and appendix.

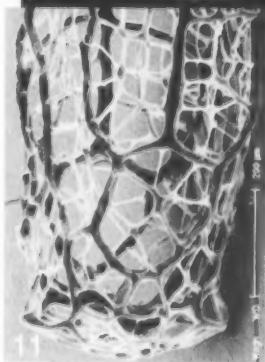
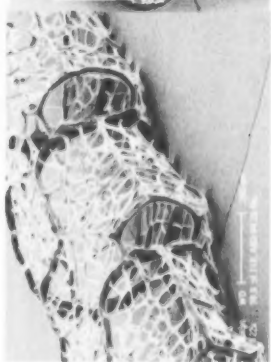
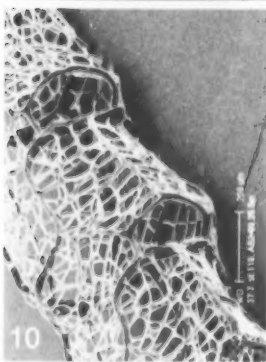
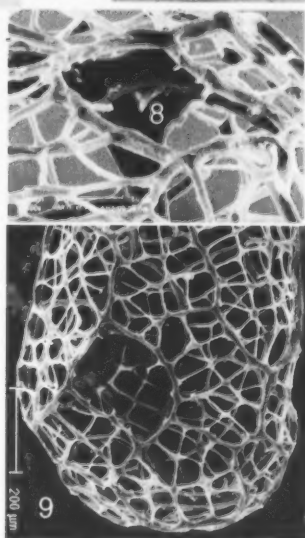
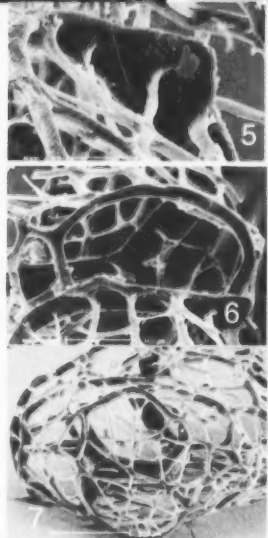
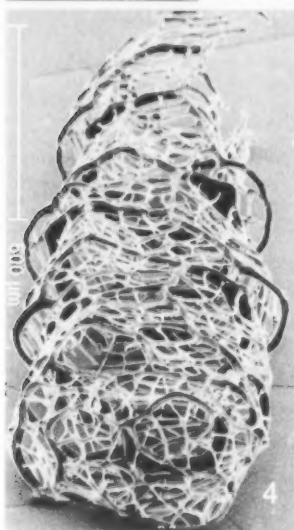
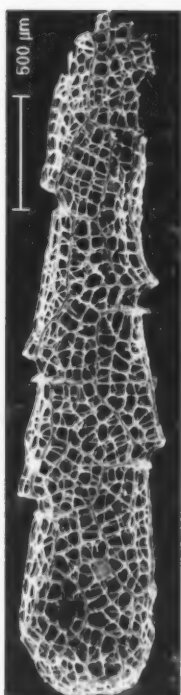
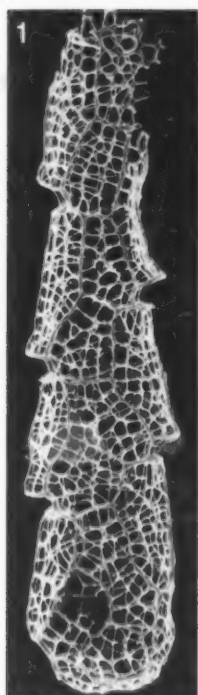


Plate 9

Figs. 1–5. *Neogothograptus thorsteinssoni* n. sp., TC 312B.

1. Paratype GSC 125979, stereopair of reverse side of mature rhabdosome with five pairs of thecae and appendix.
- 2, 5. Paratype GSC 125980.
 2. Obverse view of mature rhabdosome with five thecae and appendix.
 5. Oblique view of proximal end with outer ancora.
3. Holotype GSC 125981, stereopair of reverse side of mature rhabdosome with five pairs of thecae and appendix.
4. Paratype GSC 125982, enlargement of thecal orifice.

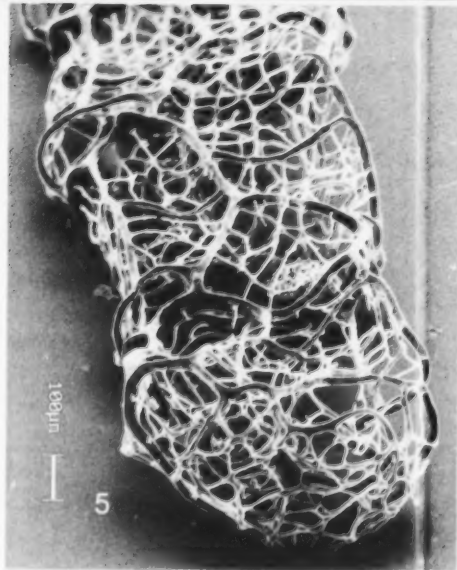
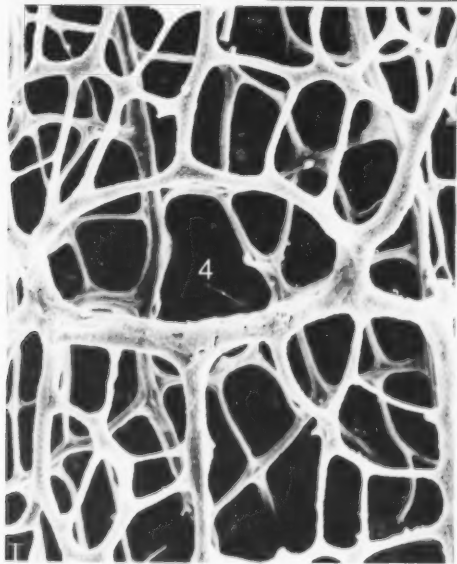
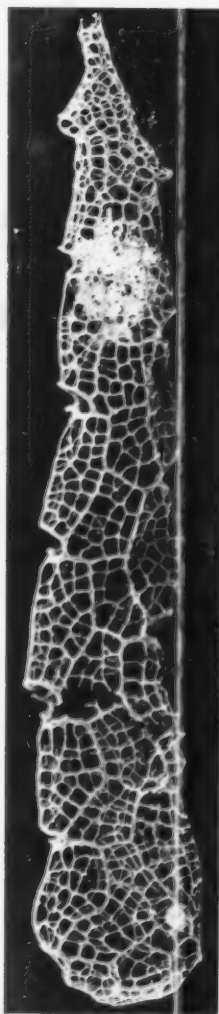
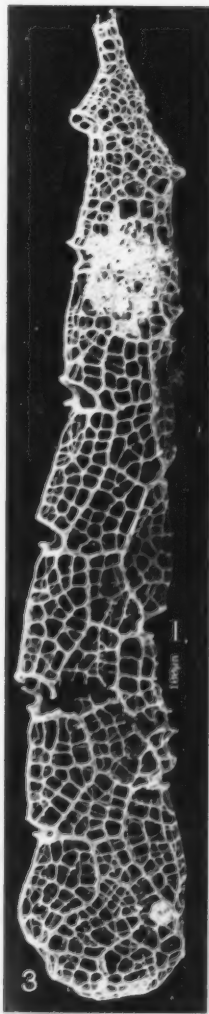
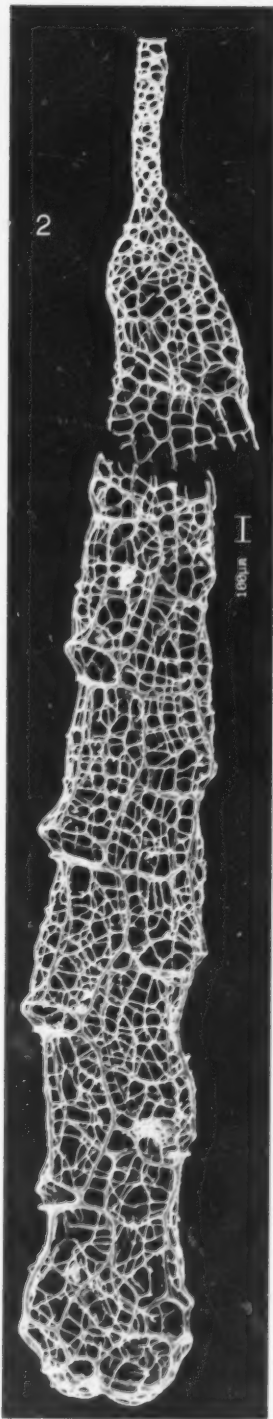
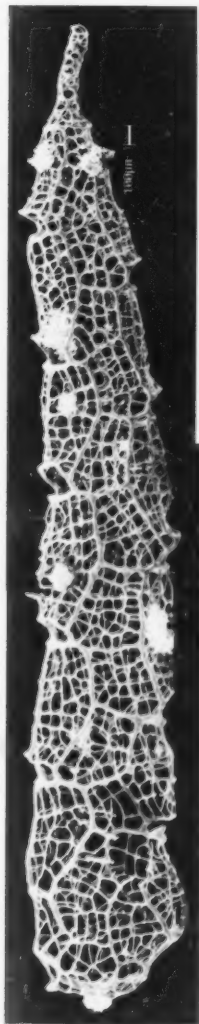
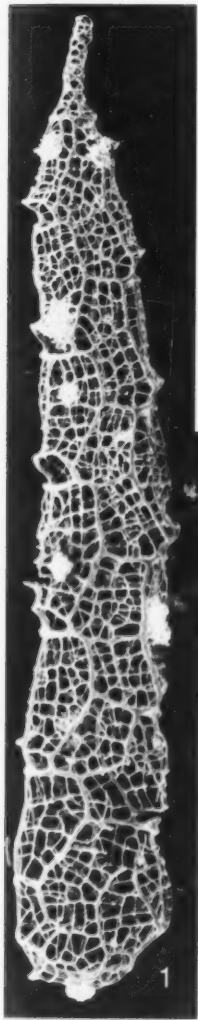


Plate 10

Figs. 1–7. *Neogothograptus thorsteinssoni* n. sp., Figs. 1, 2, 6, 7 GP-96, 12 m; 3–5 BH-57.6 m.

1, 2. Paratype GSC 125983.

1. Stereopair of reverse proximal part of rhabdosome.
2. Stereopair of proximal view of outer ancora.

3. Paratype GSC 125984, stereopair of distal part of rhabdosome with appendix.

4, 5. Paratype GSC 125985.

4. Lateral view of distal fragment of mature rhabdosome with well-developed appendix.
5. Distal view into appendix showing rounded margin.

6. Paratype GSC 125986, oblique proximal view of medial fragment of rhabdosome with distinctive genicula and strongly thickened lips.

7. GSC 125987, stereopair of ventral view of th 1¹ wall with abnormal development of first theca.

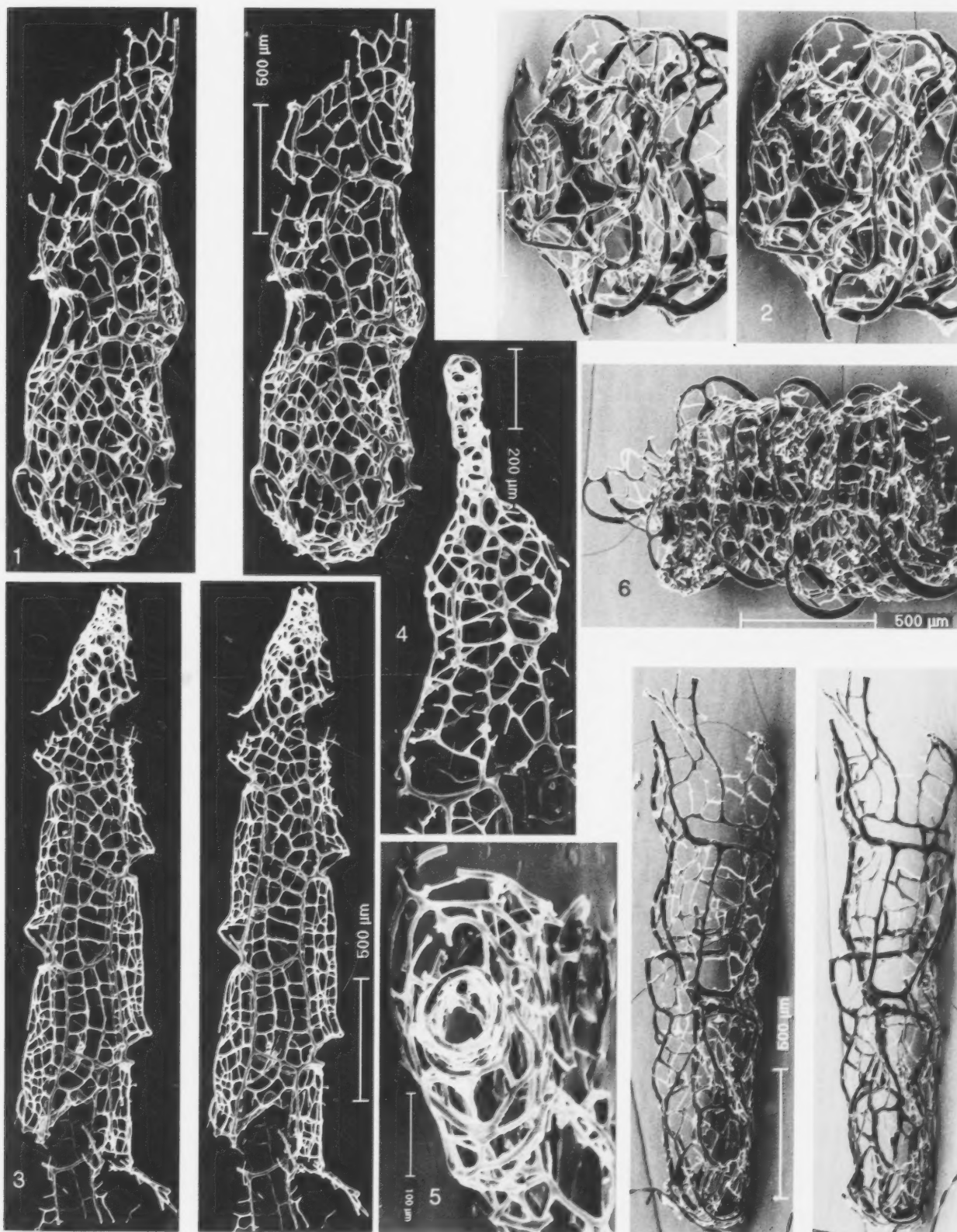


Plate 11

Figs. 1–3. *Neogothograptus alatiformis* n. sp. Holotype GSC 125988 (st. 216), TC 711C, collection C61679.

1. Stereopair of slightly oblique view of obverse side of mature rhabdosome with appendix.
2. Stereopair of proximal view showing outer ancora and position of genicular processes.
3. Stereopair of obverse side of rhabdosome.

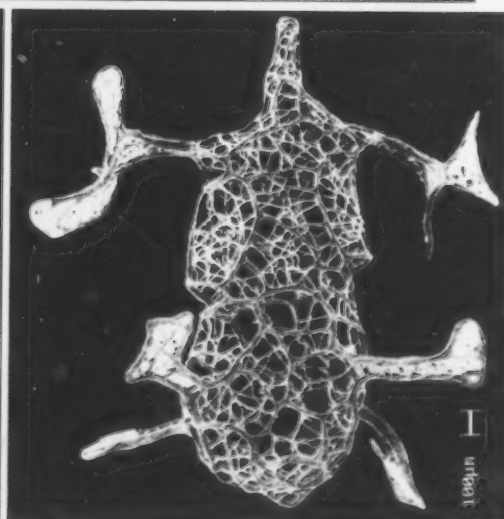
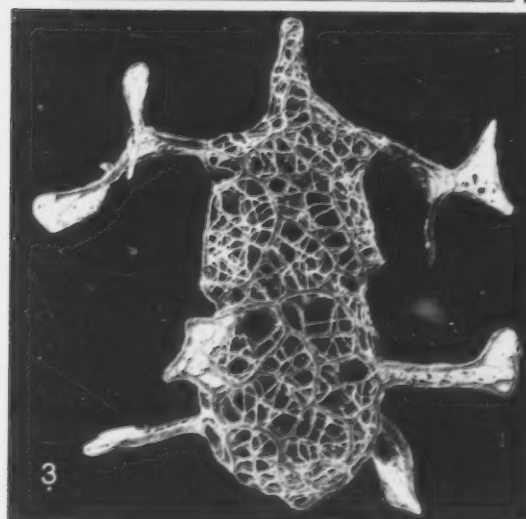
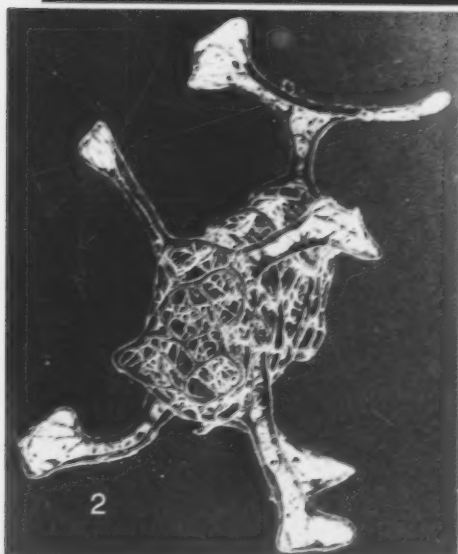
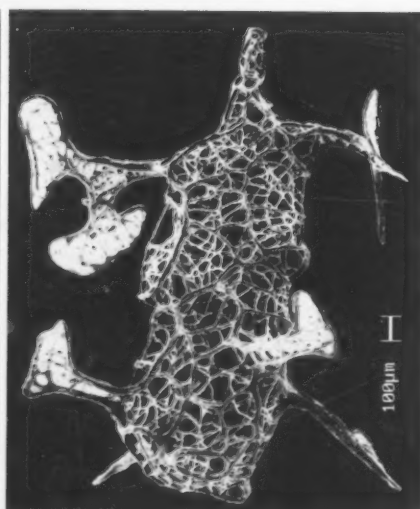
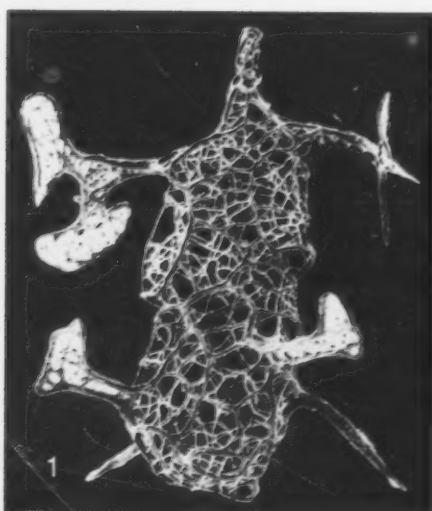


Plate 12

Figs. 1–6. *Neogothograptus alatiformis* n. sp. (st. 216), TC 711C, collection C61679.

1, 2. Paratype GSC 125989.

1. Stereopair of obverse side of rhabdosome with dense reticulum and paired lateral hood-like processes situated on both sides of singular long processes on th 2¹.
2. Enlargement of singular genicular hood of th 1¹.

3, 4, 6. Paratype GSC 125990.

3. Stereopair of reverse side of rhabdosome.
4. Proximal view of rhabdosome.
6. Distal view of rhabdosome.

5. Paratype GSC 125991, stereopair of proximal view of reverse side of rhabdosome with distinctive edges on ancora umbrella.

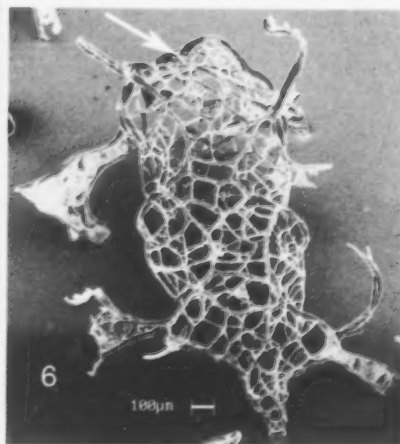
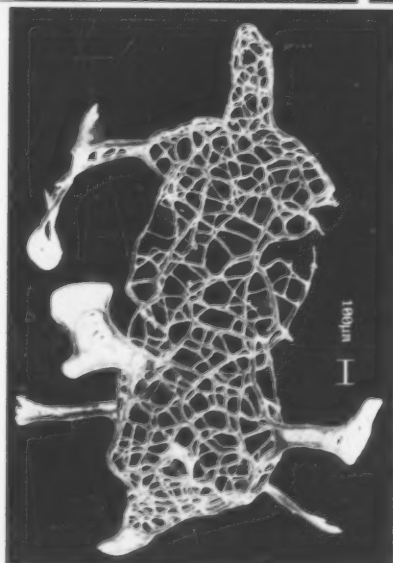
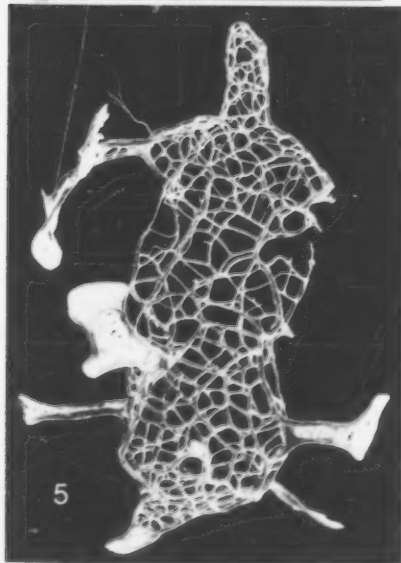
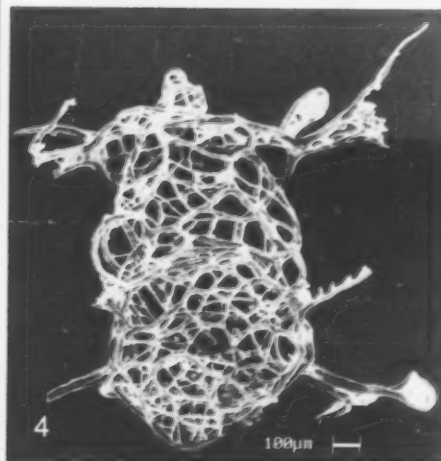
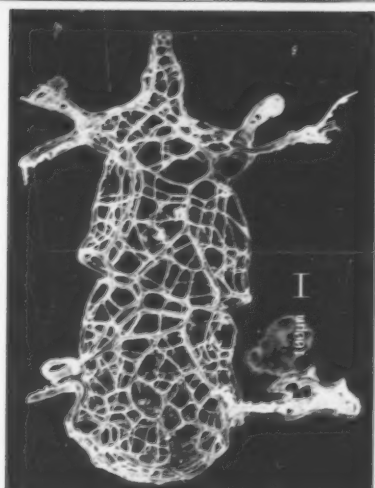
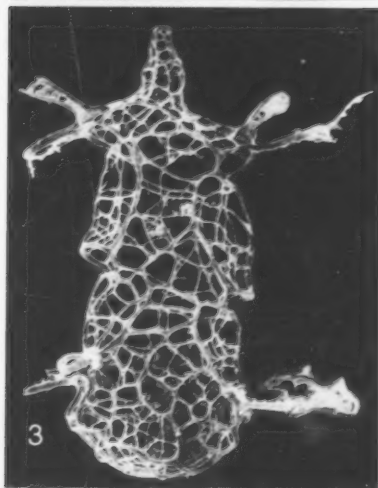
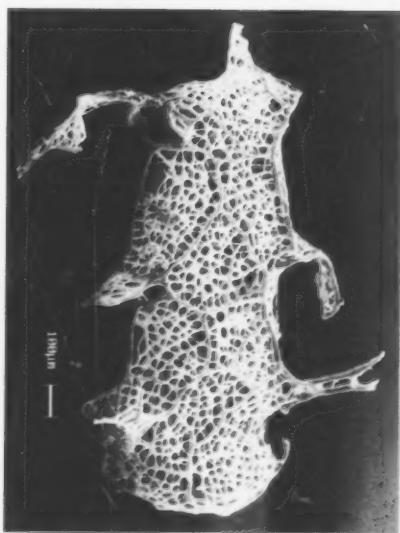
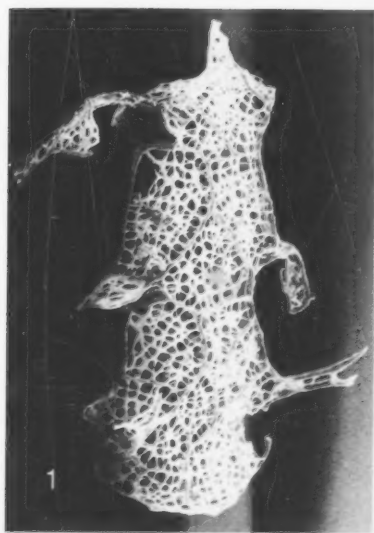


Plate 13

Figs. 1–5. *Neogothograptus alatiformis* n. sp. (st. 216), TC 711C, collection C61679.

1, 4. Paratype GSC 125992.

1. Stereopair of obverse side of rhabdosome.

4. Distal view of rhabdosome.

2. Paratype GSC 125993, reverse side of rhabdosome

3. Paratype GSC 125994, reverse side of rhabdosome.

5. Paratype GSC 125995, ventral view of th 1¹ wall.

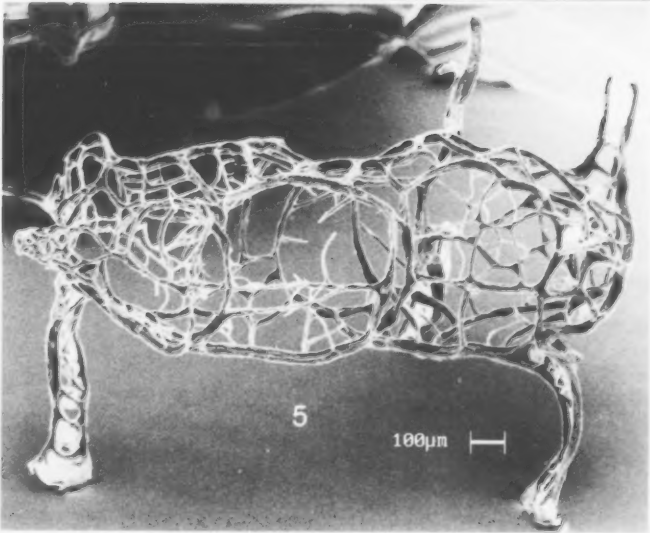
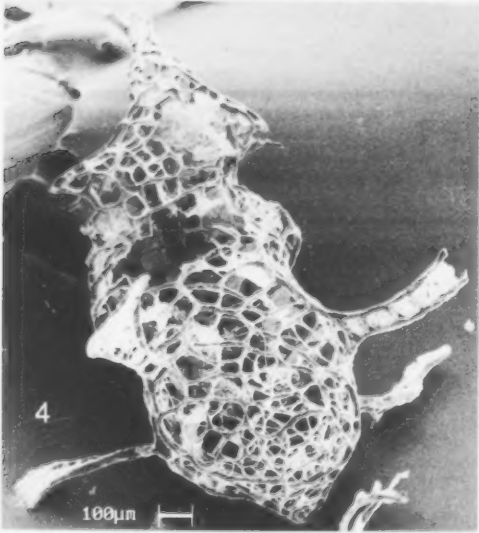
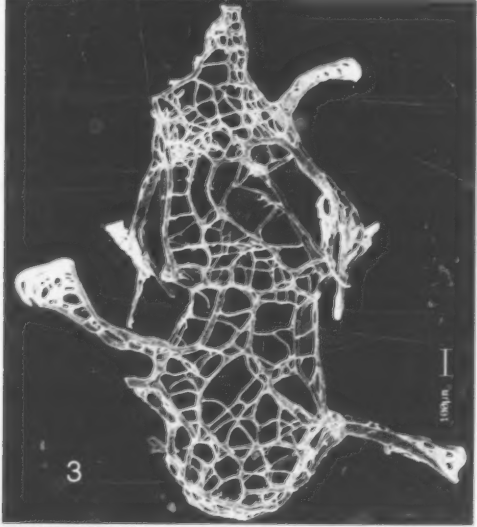
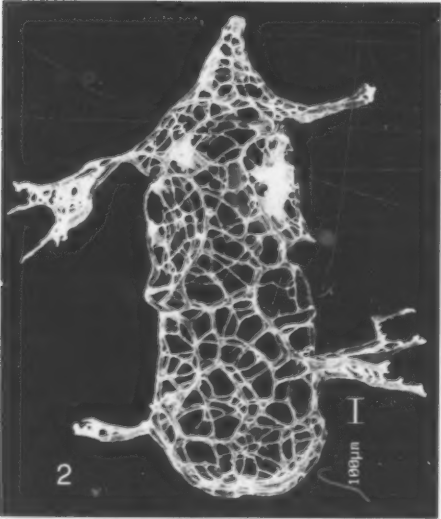
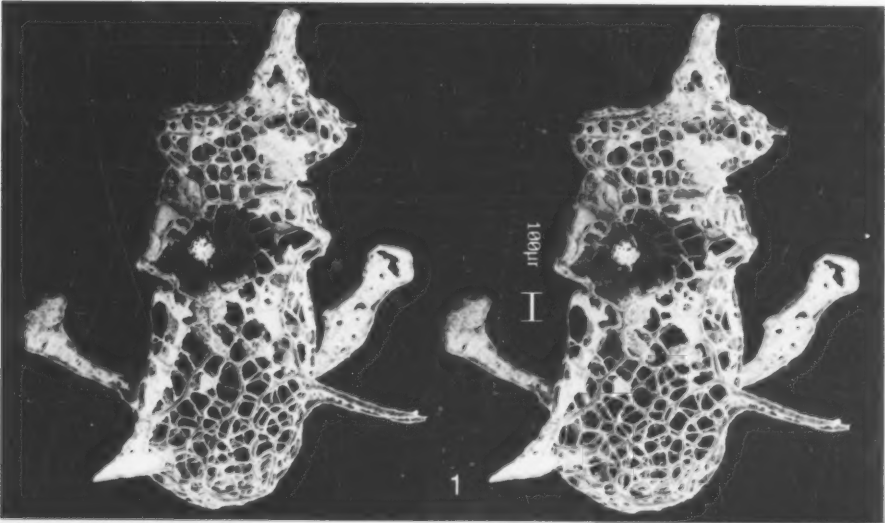


Plate 14

Figs. 1–10. *Neogothograptus alatiformis* n. sp., Paratype GSC 125996, AB2-99, 23 m.

1. Genicular process of th 1².
2. View of genicular process of th 1¹ (in front) and th 1².
3. Stereopair of latero-ventral view of th 1² wall, proximal ventral orifice with long reticular list (arrow).
4. Stereopair of proximal view of rhabdosome with outer ancora developed, proximal orifice process of reticulofusellar nature preserved (distal end not preserved).
5. Stereopair of distal view of rhabdosome with narrow appendix.
6. Enlargement of distal view of appendix.
7. Enlargement of proximal orifice process of reticulofusellar nature preserved without distal end.
8. Lateral view of appendix.
9. Stereopair of obverse side of rhabdosome.
10. Stereopair of latero-ventral view of th 1¹ wall, proximal ventral orifice with long reticular list (arrow).

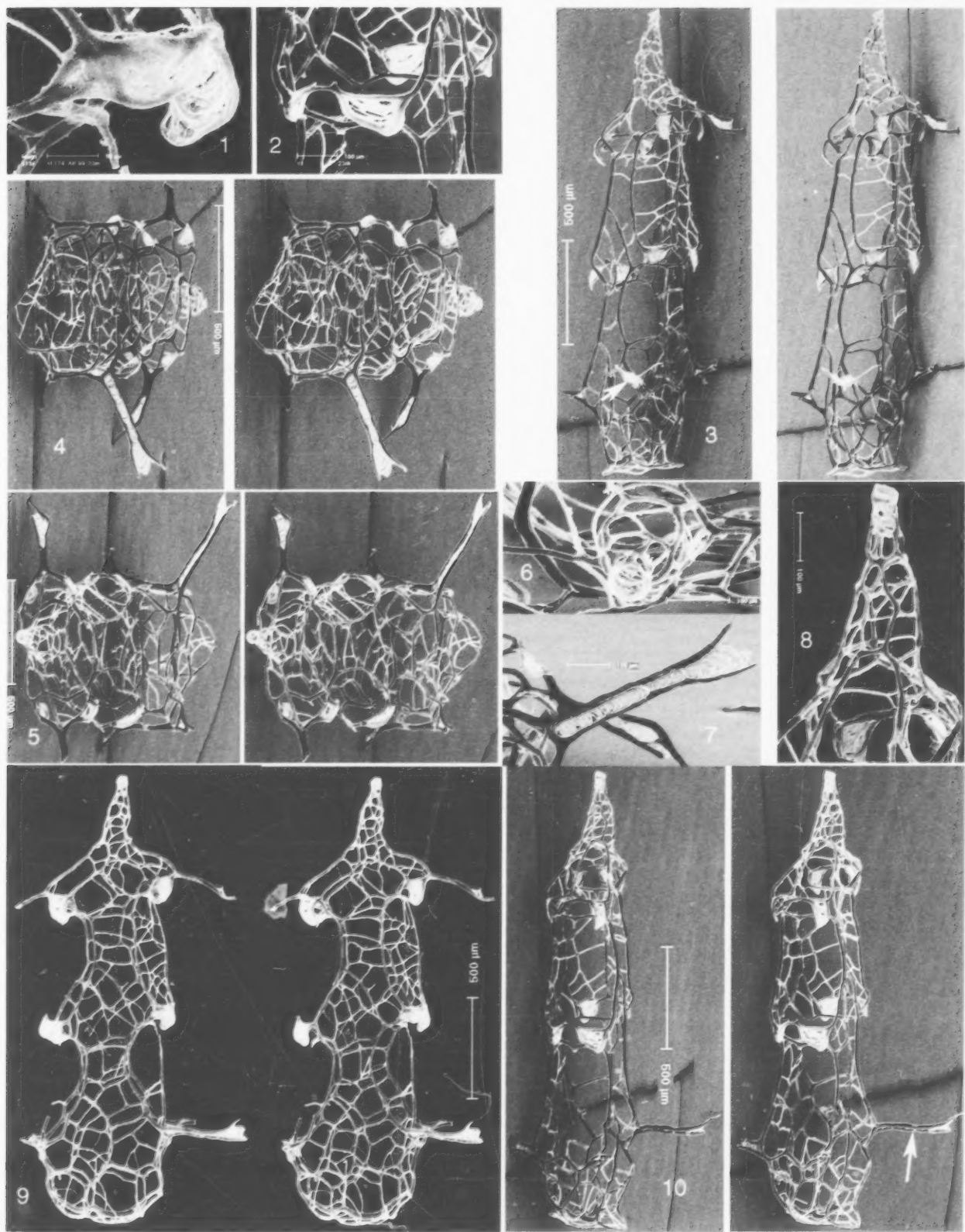


Plate 15

Figs. 1–11. *Neogothograptus alatiformis* n. sp., AB2-99, 23 m, 1–6. Paratype GSC 125997

1. Latero-ventral view of th 1¹ wall.
2. Proximal view of outer ancora.
3. Stereopair of obverse side of rhabdosome with long, broken genicular processes.
4. Enlargement of proximal end of latero-ventral view of th 1¹ wall with proximal orifice with reticulum.
5. Stereopair of proximal view of rhabdosome.
6. Stereopair of distal view of rhabdosome.

7–10. Paratype GSC 125998.

7. Immature rhabdosome, latero-ventral view of th 1¹ wall.
8. Inside view of ancora umbrella.
9. Obverse side of immature rhabdosome.
10. Latero-ventral view of th 1² wall.

11. Outside view of ancora umbrella with a few outer ancora lists.

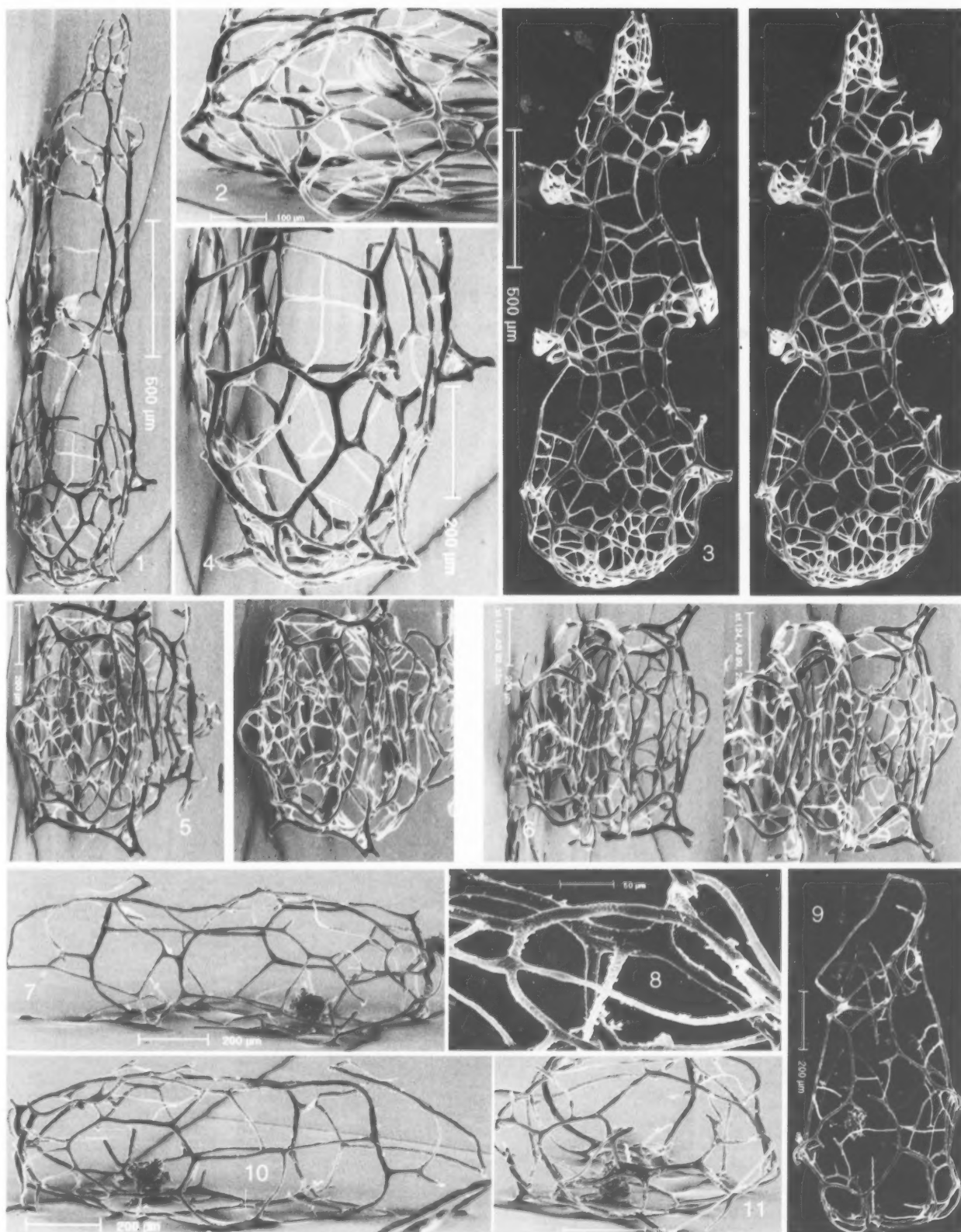


Plate 16

Figs. 1–10. *Neogothograptus alatiformis* n. sp., Paratype GSC 125999, AB2-99, 23 m.

1. Stereopair of lateral view of distal fragment of mature rhabdosome with appendix and well-preserved genicular processes.
2. Distal view of appendix and ventral wall with genicular processes.
3. Distal ventral view showing thecal orifices with processes.
4. Stereopair of distal view inside fragment of rhabdosome.
5. Enlargement of fragment of genicular processes.
6. Inside view of appendix with fragment of nema.
7. Distal view of appendix with narrow distal end.
8. Ventral view of two distal thecae and appendix.
9. Stereopair of ventro-lateral view of th 1¹ wall.
10. Enlargement of lateral view of appendix with fragment of nema inside (arrow).

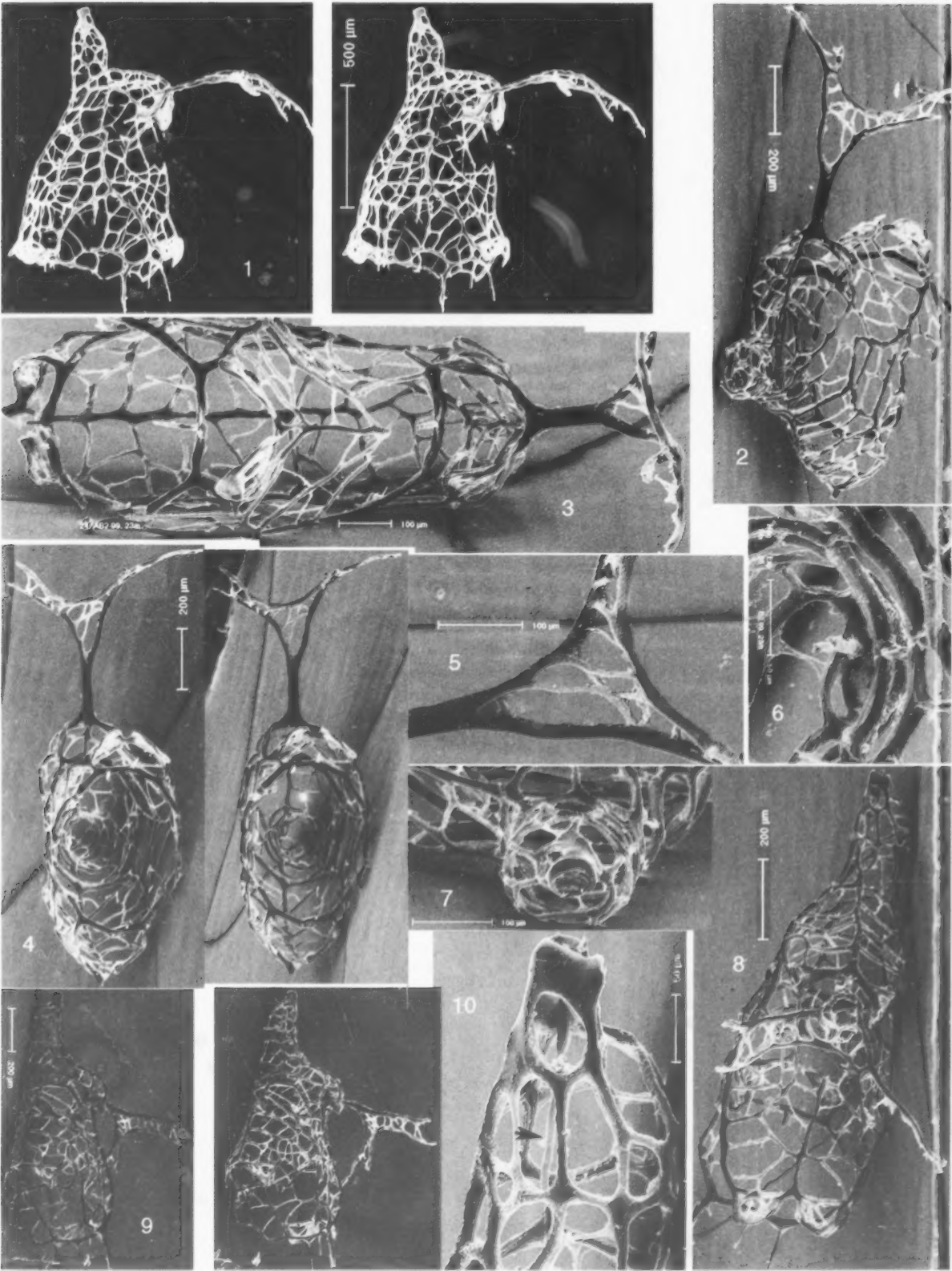


Plate 17

Figs. 1-13. *Neogothograptus melchini* n. sp.; MCM 90Y.

1, 12, 13. Paratype GSC 126000, st. 112.

1. Enlargement of outside view of ancora umbrella.
12. Stereopair of reverse view of rhabdosome.
13. Oblique proximal view of rhabdosome.

2, 6. Paratype GSC 126001.

2. Inside view of ancora.
6. Stereopair of obverse view of rhabdosome with two pairs of thecae.

3, 7, 8. Paratype GSC 126002.

3. Enlargement of thecal orifice with short mid-ventral list on lip.
7. Ventro-lateral view of distal part of rhabdosome with small appendix.
8. Ventral view of rhabdosome.

4. Holotype GSC 126003, stereopair of obverse view of rhabdosome with three pairs of thecae.

5. Paratype GSC 126004, stereopair of median fragment of rhabdosome with three thecae.

9, 10. Paratype GSC 126005.

9. Enlargement of possible nema.
10. Stereopair of ventral wall with short, possible nema fragment in sediment.

11. Paratype GSC 126006, ventro-lateral view of rhabdosome.

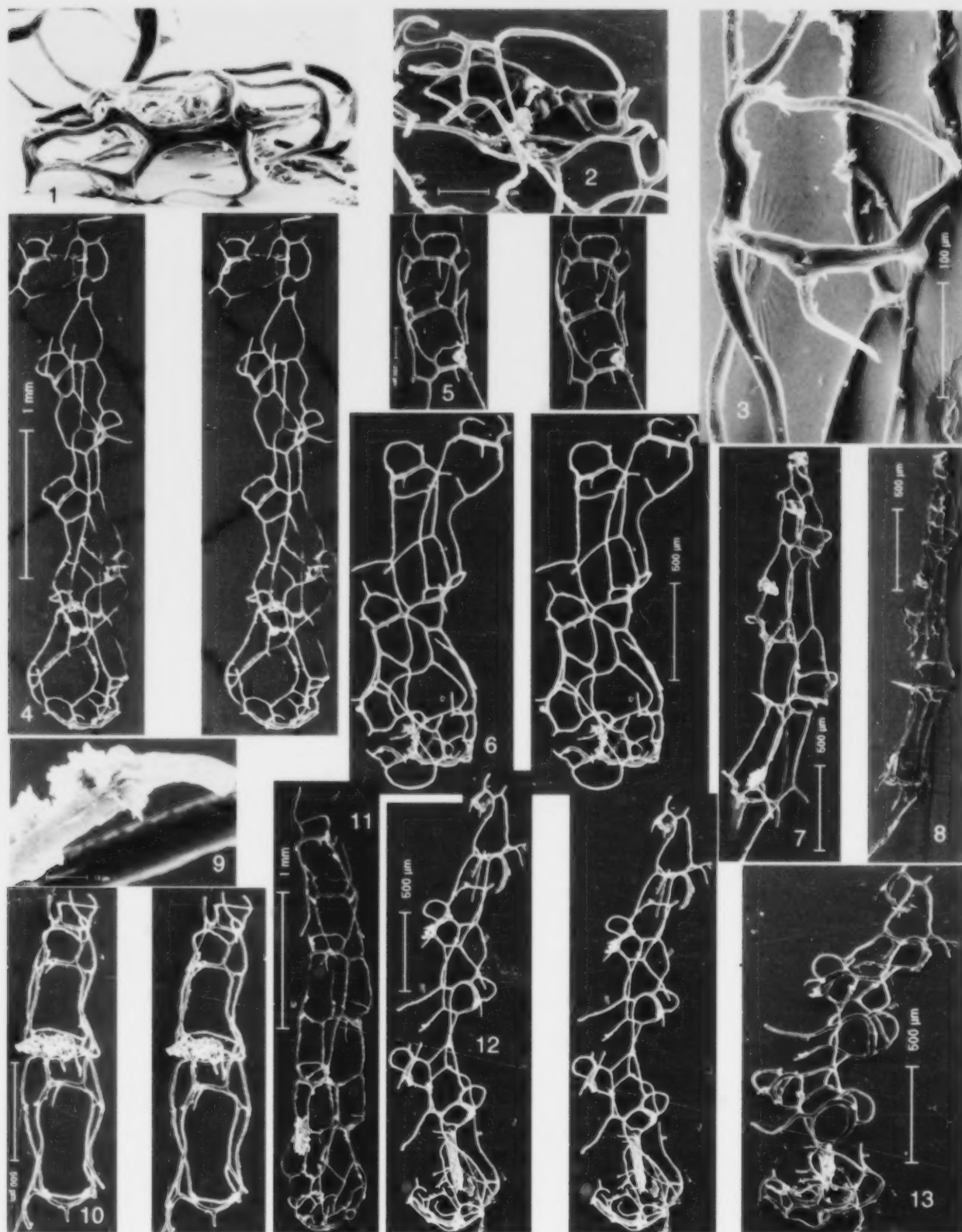


Plate 18

Figs. 1–8. *Holoretiolites manckoides* Kozłowska-Dawidziuk, 1995, RC01-1, 22 m (st. 204).

1, 4–6. GSC 126007.

1. Stereopair of oblique lateral view of the most complete rhabdosome with six pairs of thecae.
4. Enlargement of proximal end with fragment of virgella preserved.
5. Stereopair of reverse view of rhabdosome.
6. Enlargement of thecal orifice.

2. GSC 126008, early stage of development of rhabdosome with first proximal ventral orifice developed.

3, 7. GSC 126009

3. Stereopair of fragment of obverse side of rhabdosome.
7. Enlargement of proximal end.

8. GSC 126010, stereopair of reverse side of rhabdosome with two pairs of thecae.

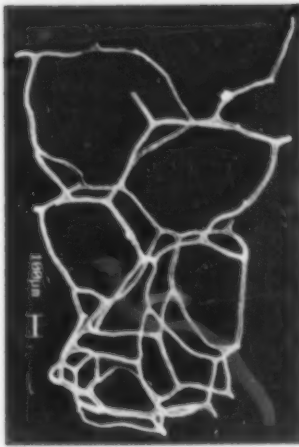
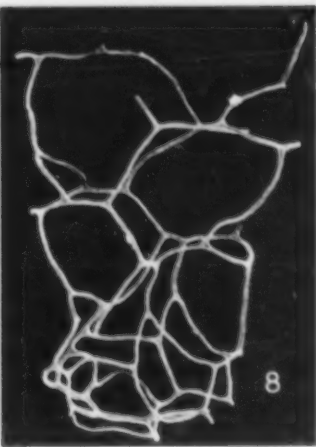
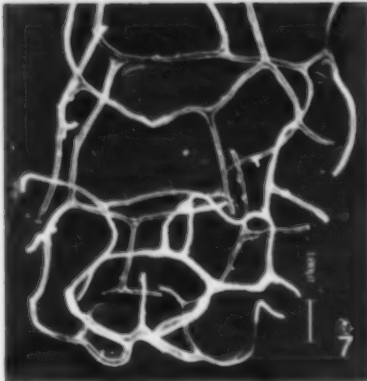
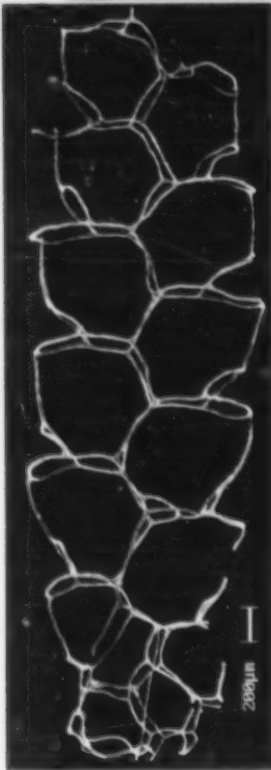
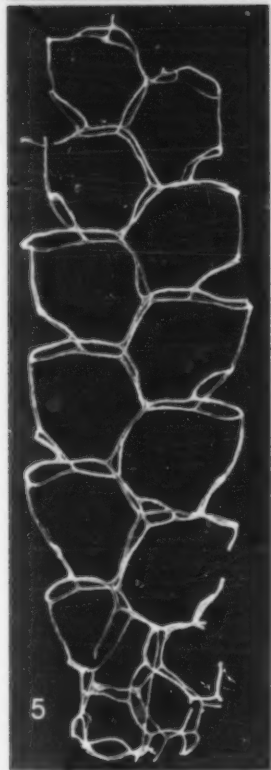
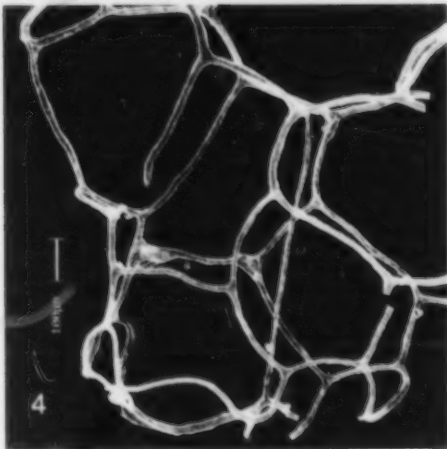
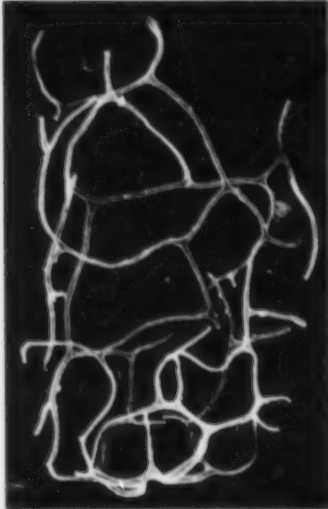
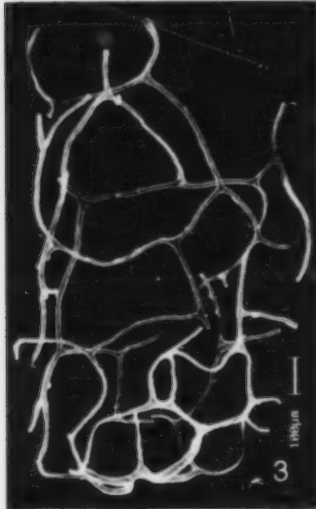
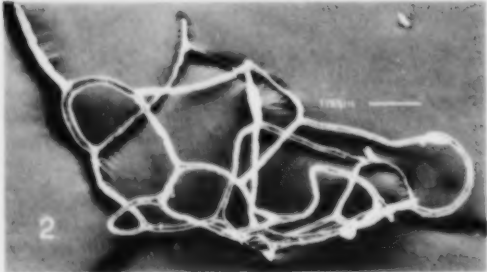
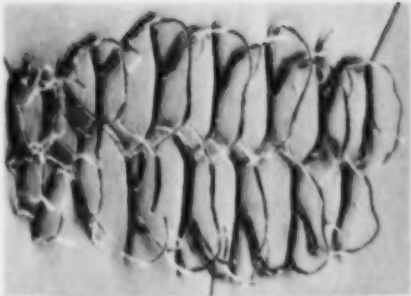
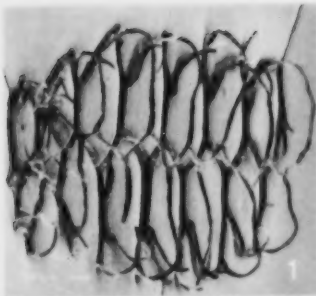


Plate 19

Figs. 1–10. *Holoretiolites manckoides* Kozłowska-Dawidziuk, 1995, AB2-99, 58.5 m.

1, 2. GSC 126011

1. Stereopair of lateral view of early growth stage of rhabdosome.
2. Oblique distal view of specimen.

3, 4. GSC 126012.

3. Outside ventral view of thecal orifice.
4. Inside ventral view of thecal orifice.

5. GSC 126013, fragment of ancora of mature specimen showing cross-section of virgella (arrow).

6. GSC 126014, stereopair of reverse side of young specimen with one pair of thecae.

7–9. GSC 126015.

7. Stereopair of reverse side of rhabdosome with three pairs of thecae (distal part of specimen is destroyed).
8. Oblique distal view of proximal part of rhabdosome.
9. Distal view of ancora.

10. GSC 126016, stereopair of obverse view of rhabdosome with one pair of thecae.

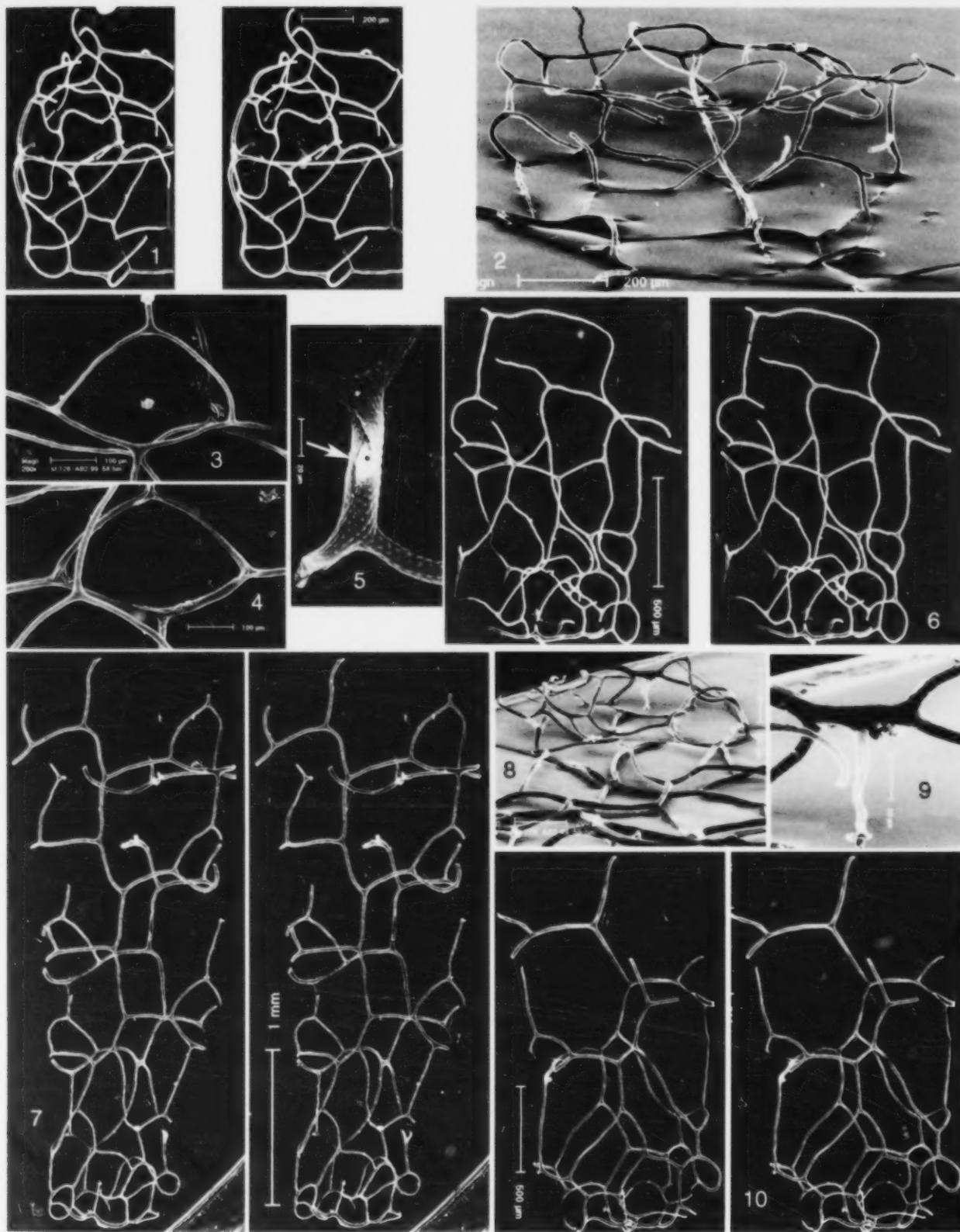


Plate 20

Figs. 1–11. *Holoretiolites atrabecularis* Kozłowska-Dawidziuk, 1995, RC-01-1, 21 m.

1, 6. GSC 126017

1. Stereopair of ventro-lateral view of proximal end of rhabdosome with two first thecae preserved.
6. Proximal view of specimen.

2, 7. GSC 126018

2. Stereopair of ventro-lateral view of proximal end of rhabdosome with two first thecae preserved.
7. Proximal view of specimen

3. GSC 126019, stereopair of fragment of medial part of rhabdosome.

4. GSC126020, fragment of medial part of rhabdosome.

5. GSC126021, proximal end of rhabdosome, reverse side.

8. GSC126022, stereopair of medial part of fragment of rhabdosome, lateral view.

9. GSC 126023, medial part of fragment of rhabdosome.

10. GSC 126024, stereopair of medial part of rhabdosome fragment, lateral-ventral view.

11. GSC 126025, stereopair of medial part of rhabdosome fragment, ventral view.

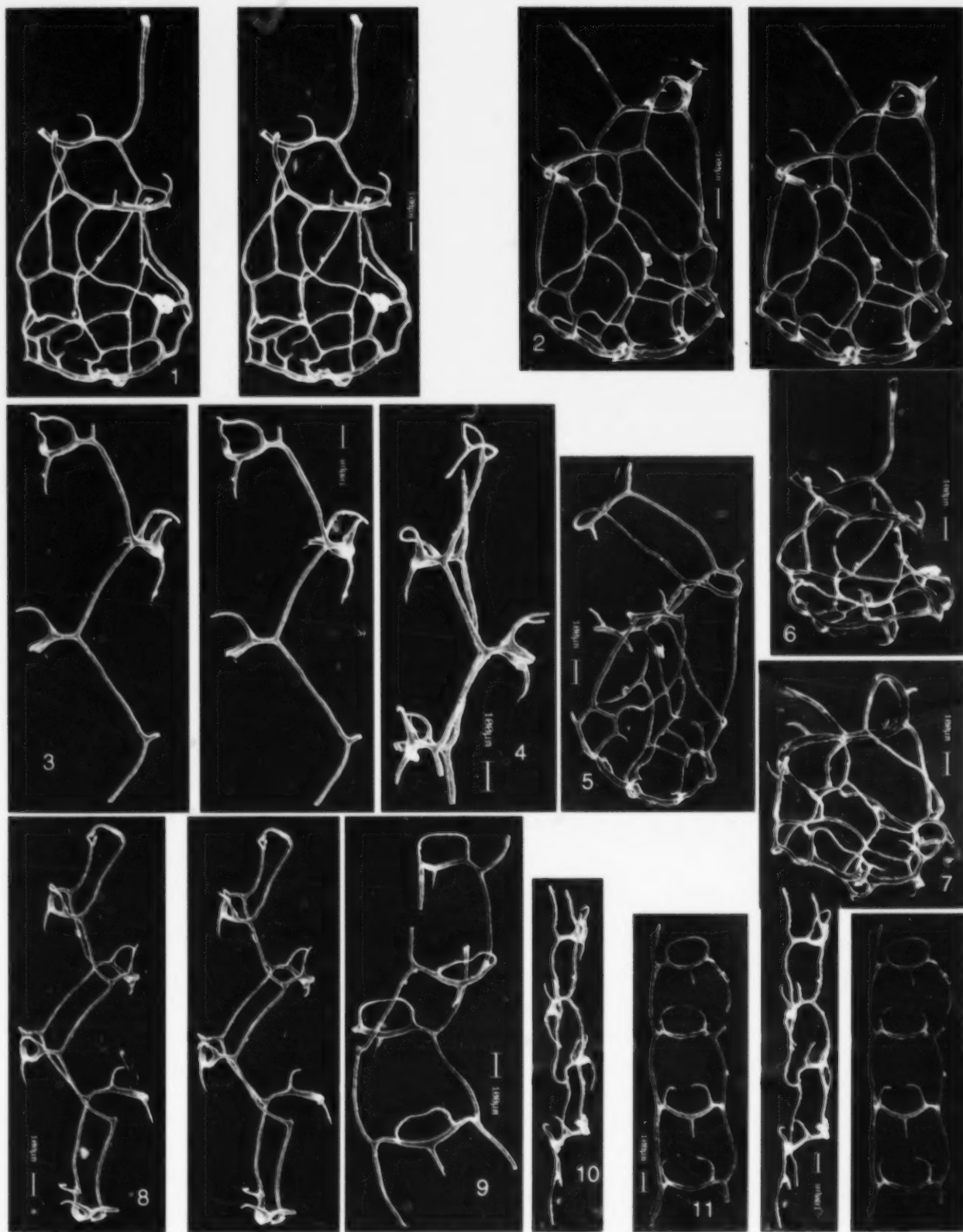


Plate 21

Figs. 1, 2, 4-6, 8, 10. *Spinograptus spinosus* (Wood, 1900) (st. 117), GP 96 12 m.

1, 4-6, 8. GSC 126026.

1. Stereopair of obverse view of rhabdosome with two pairs of thecae.
4. Inside view of ancora with virgella.
5. Stereopair of ventral view of rhabdosome.
6. Stereopair of outside view of rhabdosome.
8. Enlargement of apertural processes with reticulofusellar structure on their distal-most part.

2. GSC 126027, stereopair of obverse view of rhabdosome with two pairs of thecae.

10. GSC 126028, stereopair of lateral-ventral view of obverse side of rhabdosome with three pairs of thecae developed.

Figs. 3, 7, 9. *Spinograptus clathrospinosus* Eisenack, 1951, GSC 126029, GP 96 12 m.

3. Enlargement of th 1² orifice with apertural processes.
7. Enlargement of apertural processes with reticulofusellar structure on their distal parts.
9. Stereopair of ventro lateral view of rhabdosome with broken proximal end.

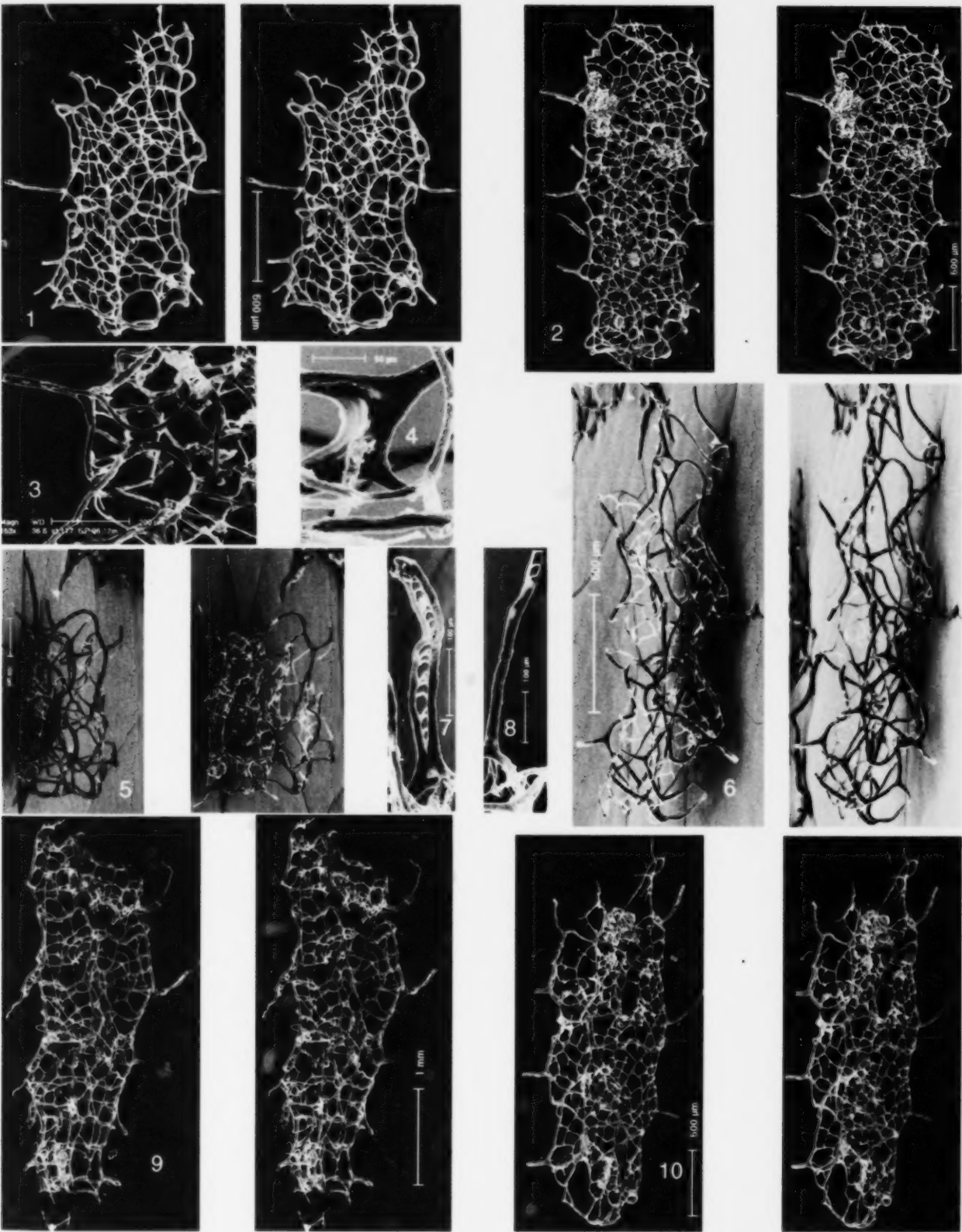


Plate 22

Figs. 1–10. *Spinograptus quadratus* Lenz, 1993; SJF 155 m.

1, 2. GSC 126030.

1. Distal fragment of mature rhabdosome, lateral view.
2. Enlargement of theca and apertural process.

3. GSC 126031, enlargement of thecal profile, no apertural process.

4, 8. GSC 126032.

4. Fragment of mature rhabdosome, lateral view.
8. Enlargement of thecal profile, small apertural process.

5. GSC 99173, holotype, obverse side of rhabdosome with nine pairs of thecae.

6. GSC 99172, stereopair of thecal walls with well-developed, paired genicular processes.

7. GSC 126033, enlargement of apertural process.

9. GSC 126034, stereopair of fragment of rhabdosome, lateral view.

10. GSC 99171, stereopair of proximal and medial part of rhabdosome.

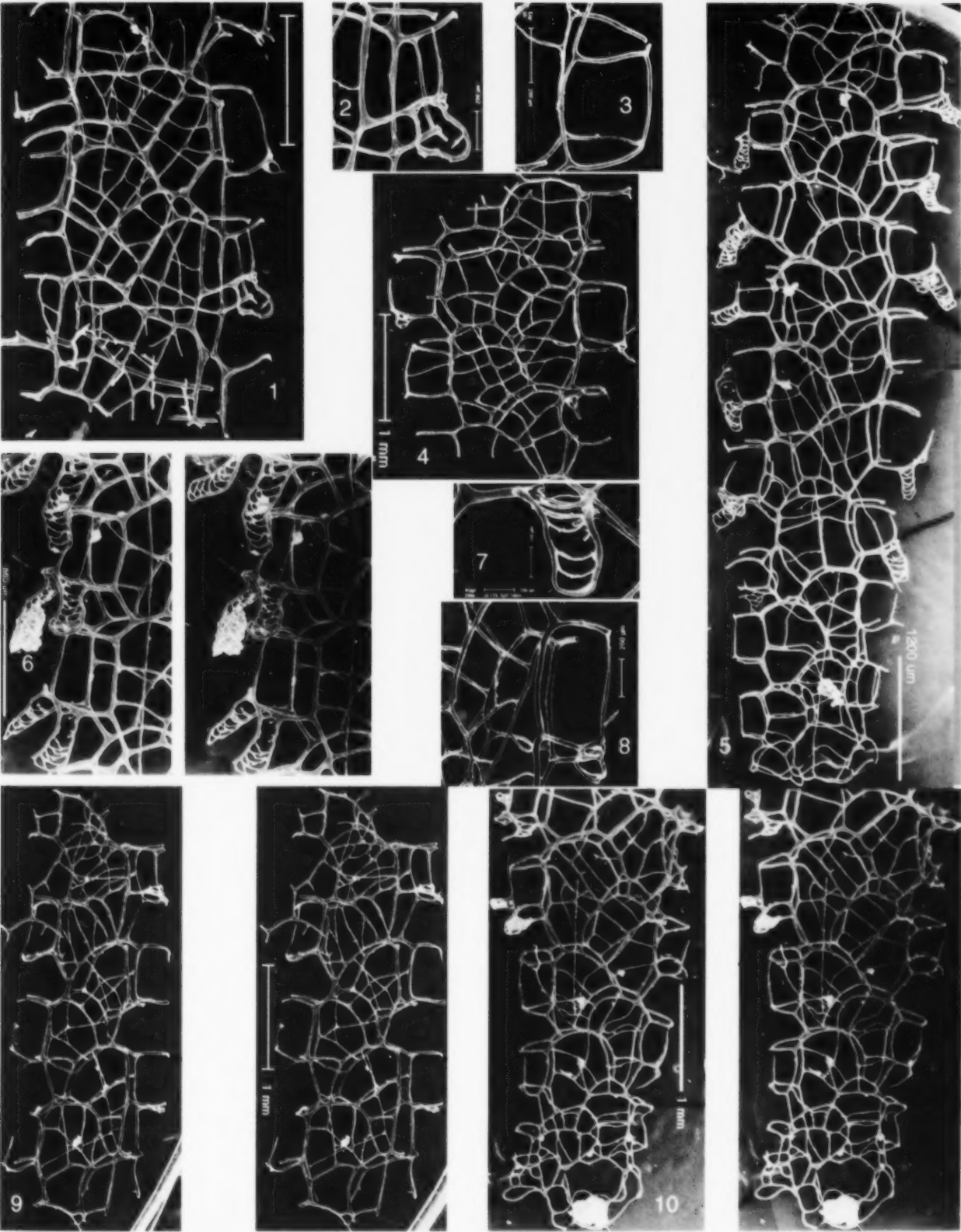


Plate 23

Fig. 1-5. *Plectograptus macilentus* (Törnquist, 1887)

1. GSC 126035, BH 91, 57.6 m, proximal part of rhabdosome with two first thecae developed, obverse view.
2. GSC 126036, MCM 91Y, proximal part of rhabdosome, lateral view.
3. GSC 126037, MCM 90Y, proximal part of rhabdosome, lateral view.
4. GSC 126038, MJB 029, mature rhabdosome with nine thecae developed, lateral view.
5. GSC 126039, MCM 90Y, obverse view of young rhabdosome with two pairs of thecae; nema preserved.

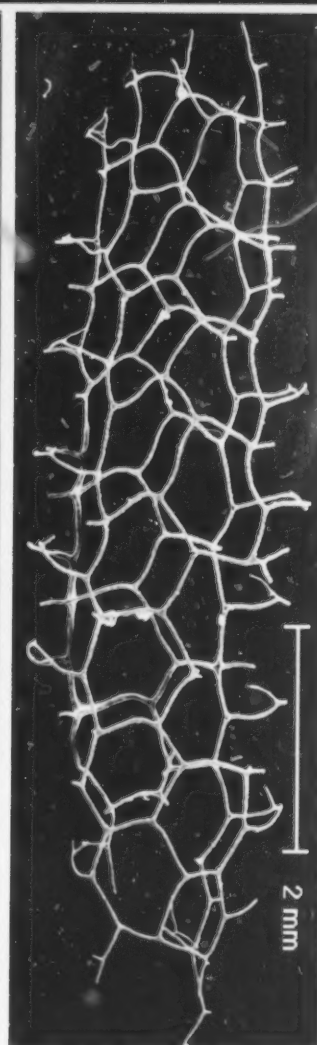
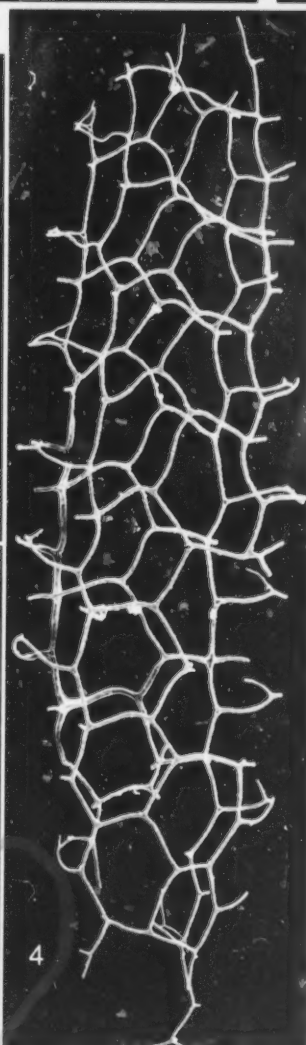
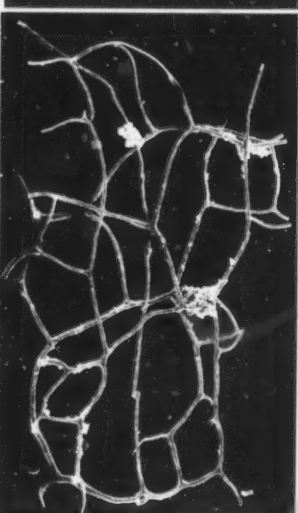
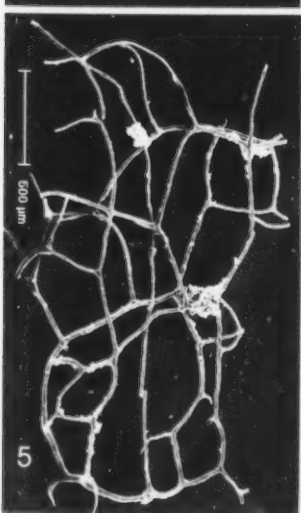
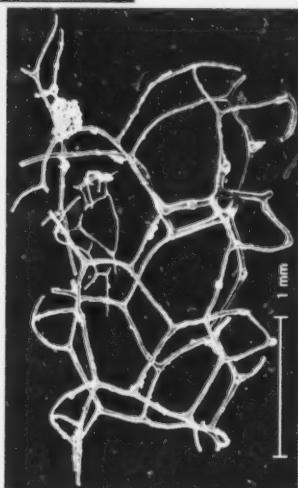
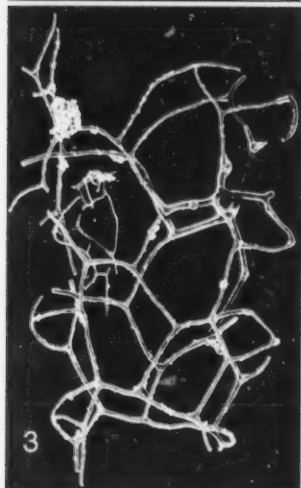
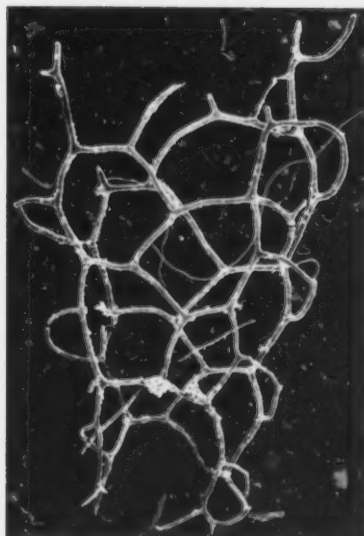
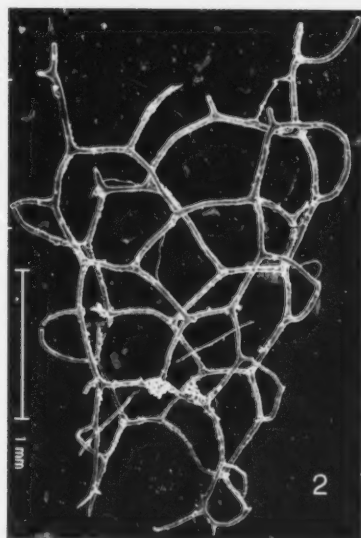
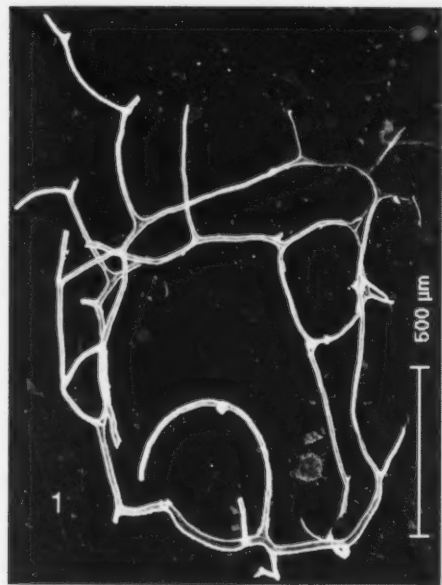


Plate 24

Figs. 1–3, 7. *Plectograptus robustus* (Obut and Zaslavskaya, 1983), GSC126040, BH-91, 57.6 m (st. 171).

1. Outside view of ancora.
2. Inside view of ancora.
3. Stereopair of proximal part of rhabdosome, lateral view.
7. Stereopair of proximal part of rhabdosome, ventral view.

Figs. 4–6, 8–12. *Plectograptus macilentus* (Törnquist, 1887), BH-91, 57.6 m (st. 171).

4–6, 8–12. GSC 126041.

4. Enlargement of inside view of proximal ventral orifice, th 1² side.
5. Outside view of ancora umbrella and ventral wall of th 1¹ side.
6. Inside view of ancora umbrella and ventral wall of th 1² side.
8. Outside view of ancora.
9. Ventral view of ventral wall of th 1¹ side.
10. Enlargement of first theca.
11. Stereopair of reverse side of young rhabdosome with three first thecae.
12. Stereopair of oblique view of ventral wall of th 1¹ side.

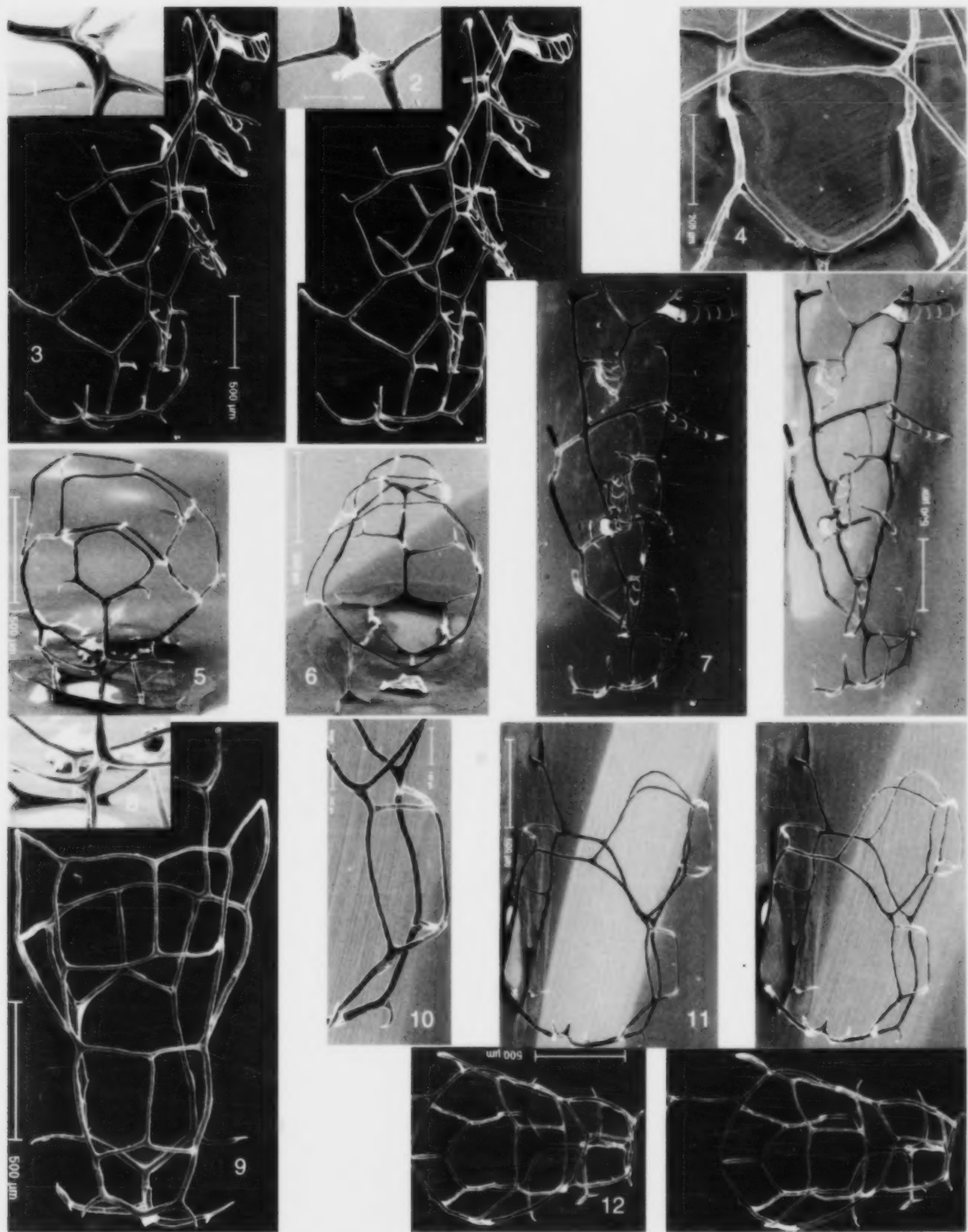


Plate 25

Figs. 1–8. ?*Plectograptus* sp. BH2-92 m.

1, 2, 5, 8. GSC 126042.

1. Oblique view of fragment of rhabdosome with mid-ventral lists and lip.
2. Stereopair of outside view with genicular processes.
5. Oblique lateral view of ventral wall.
8. Stereopair of oblique lateral view.

3. GSC 126043, outside view of portion of ventral wall with fragment of ancora sleeve wall.

4. GSC126044, fragment of ancora sleeve wall.

6, 7. GSC 126045.

6. Enlargement of fragment of ancora sleeve wall showing ancora sleeve process.
7. Fragment of ancora sleeve wall with some ventral lists.

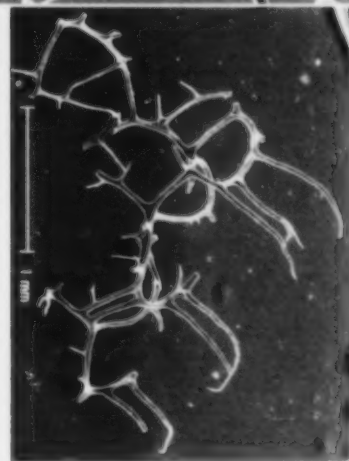
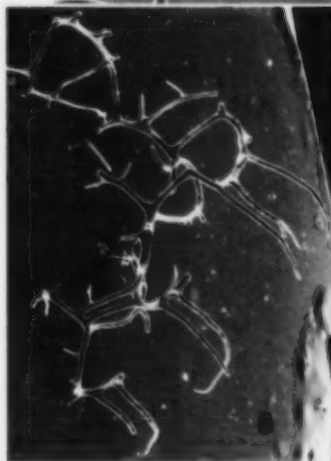
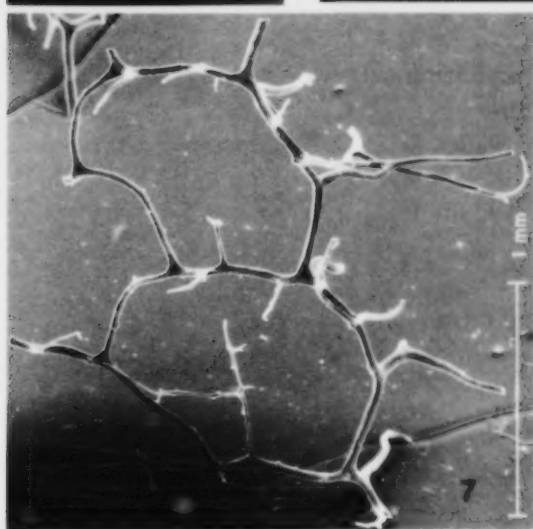
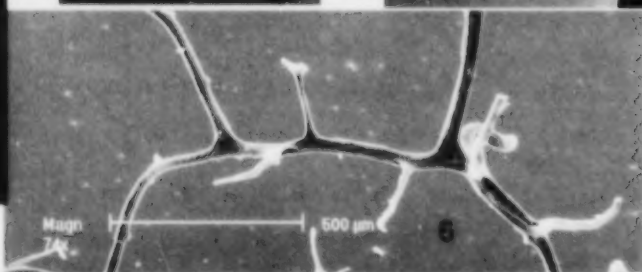
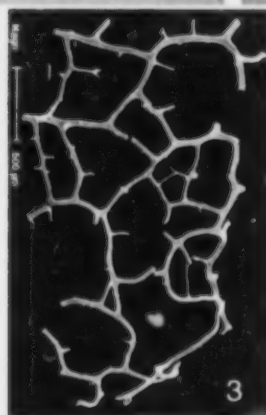
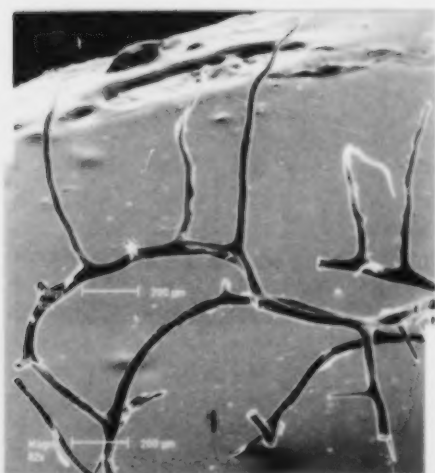


Plate 26

Fig. 1. *Spinograptus clathrospinosus* (Eisenack, 1951).

1. GSC 126046, HH 112.5 m, mature rhabdosome with genicular processes well preserved, $\times 10$.

Figs. 2, 10. *Spinograptus spinosus* (Wood, 1900).

2. GSC 126047, SJF 145 m; 2. mature rhabdosome, $\times 10$.
10. GSC 126048, HH 72 m, fragment of rhabdosome, $\times 10$.

Figs. 3, 4, 8, 9, 13, 14. *Plectograptus robustus* (Obut and Zaslavskaya, 1983).

3. GSC 126049, HH 55.5 m, rhabdosome with well-developed nematularium, $\times 10$.
4. GSC 126050, BH2, 235 m, young rhabdosome with thick nema preserved, $\times 14$.
8, 14. GSC 126051, BH2, 235 m, partial long rhabdosome with preserved nema, lateral view, $\times 20$ and $\times 10$.
9. GSC 126052, BH2, 235 m, enlargement of 14, $\times 20$.
13. GSC 126053, CP 1470' (480.1 m), rhabdosome with 10 pairs of thecae developed, $\times 11$.

Figs. 5, 6. *Neogothograptus thorsteinssoni* n. sp. mature rhabdosomes with appendixes, $\times 8$.

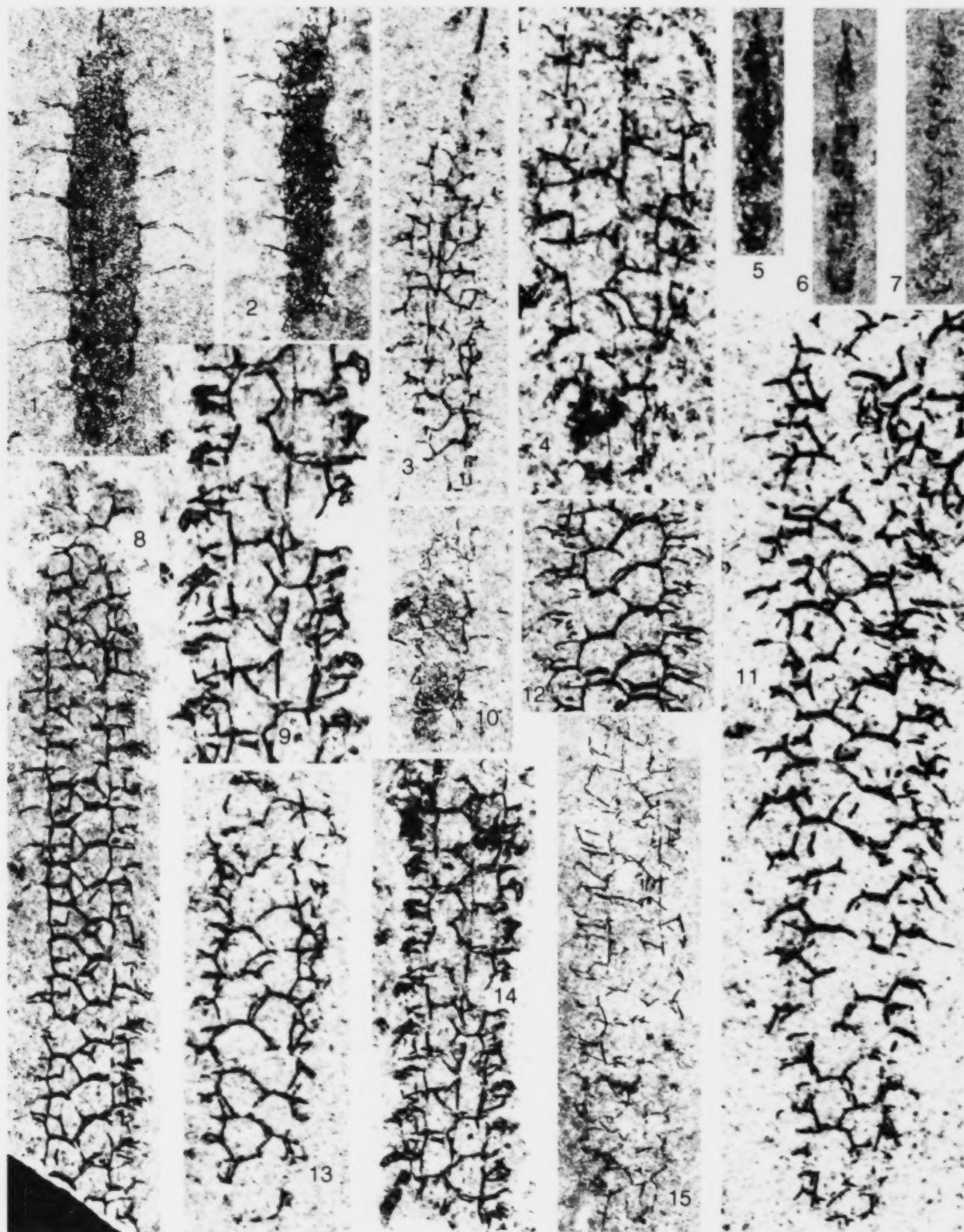
5. GSC 126054, SJF 145 m.
6. GSC 126055, HH 72 m.

Fig. 7. ?*Neogothograptus purus labiatus* n. subsp. GSC 126056, TC 3B. Mature rhabdosome with appendix, $\times 8$.

Figs. 11, 12. *Spinograptus* sp. BH2 135 m.

11. GSC 126057, mature rhabdosome, obverse view, $\times 8$.
12. GSC 126058, fragment of mature rhabdosome with genicular processes well developed, $\times 8$.

Figs. 15. *Plectograptus macilentus* (Törnquist, 1887), TC #2, GSC 126059, rhabdosome with nema preserved, $\times 8$.



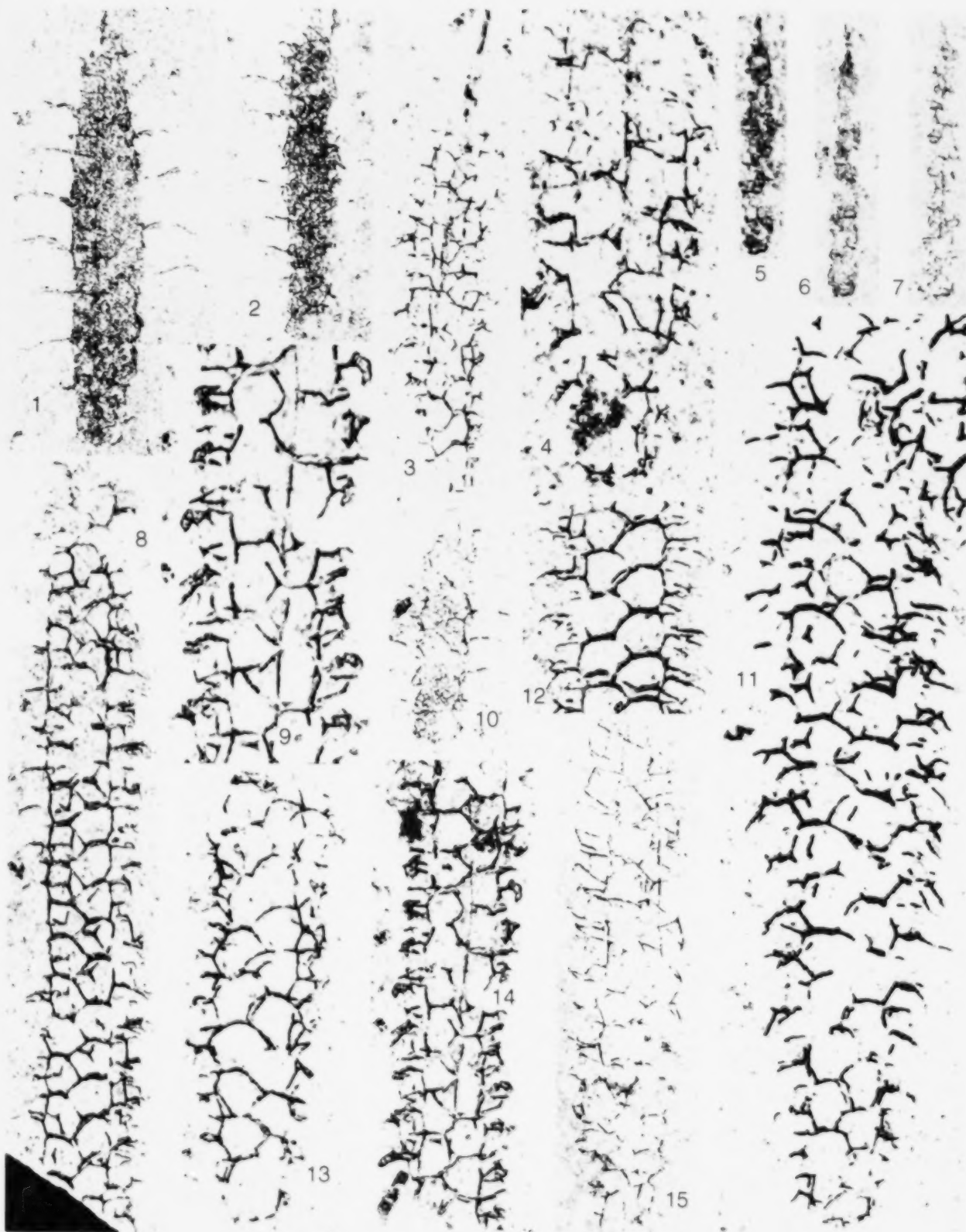


Plate 27

Figs. 1–7, 9. *Colonograptus colonus heathcotensis* (Rickards and Sandford, 1998).

1. GSC 126060, BH2-98, 146.5 m, stereopair.
2. GSC 126061, BH2-98, 146.5 m.
3. GSC 126062, BH2-98, 146.5 m, stereopair.
4. GSC 126063, BH1-91, 57.6 m.
5. GSC 126064, BH2-98, 153 m.
6. GSC 126065, SB-97, A1.5 m, stereopair, showing long, paired thecal lappets
7. GSC 126067, BH2-98, 146.5 m, note thickened virgella.
9. GSC 126068, BH2-98, 146.5 m, note long curved thecal lappets.

Figs. 8, 10–18. *Saetograptus linearis* (Bouček, 1936)

8. GSC 126069, SB D#2.
10. GSC 126070, SB D#2, stereopair, note bifurcation of thecal spines and flaring sicular aperture.
11. GSC 126071, SB-97, D75 m.
12. GSC 126072, SB D#2.
13. GSC 126073, SB-97, D75 m, note trifurcating thecal spines.
14. GSC 126074, SB D#2.
15. GSC 126075, SB D#2.
16. GSC 126076, SB-97, D75 m, note trifurcation of thecal spines.
17. GSC 126077, SB-97, D75 m.
18. GSC 126078, SB-97, D75 m, note long, sicular dorsal spine.

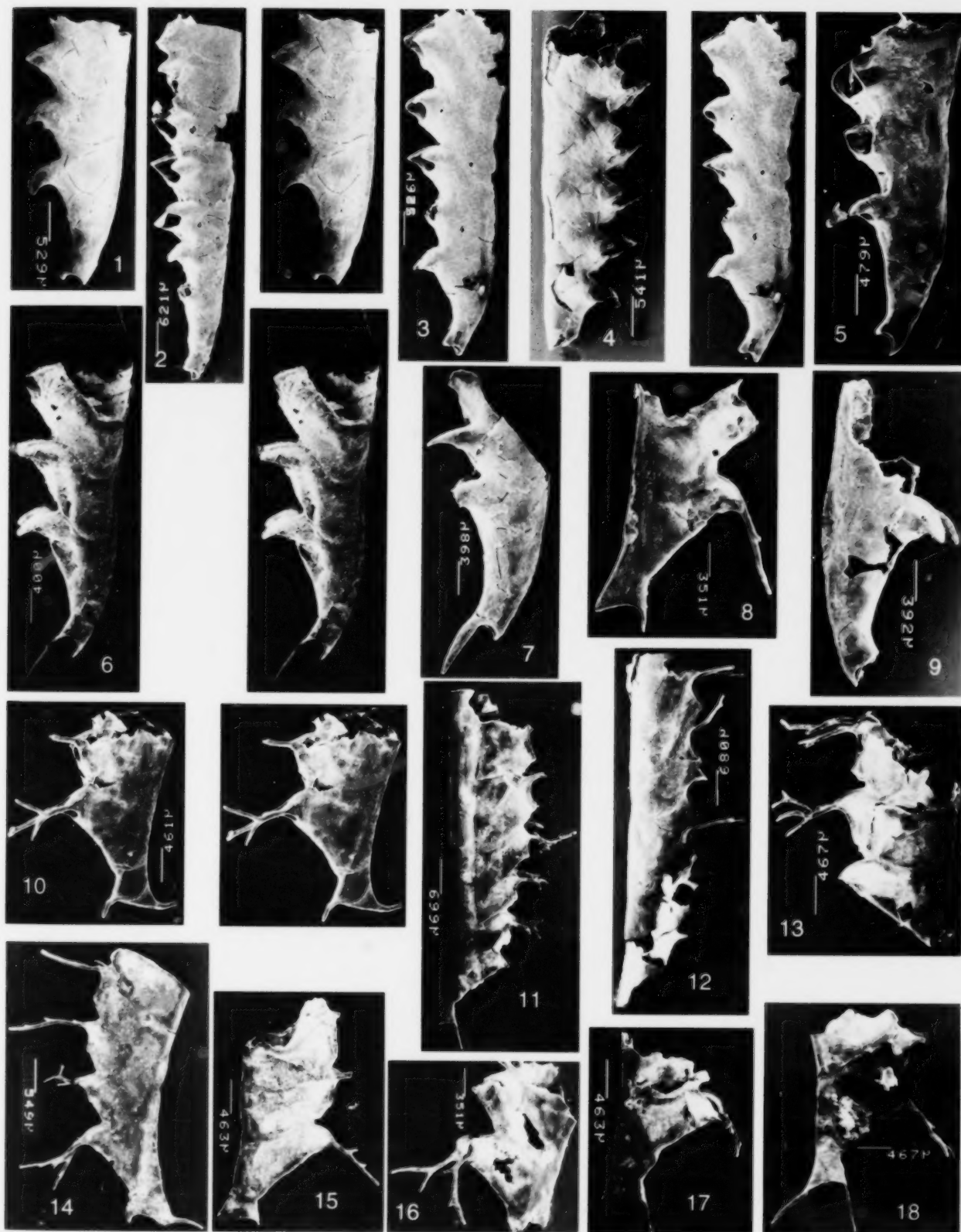


Plate 28

Figs. 1–5. *Saetograptus varians* (Wood, 1900); northeastern Cornwallis Island (locality 312B).

1. GSC 126079.
2. GSC 126080.
3. GSC 126081.
4. GSC 126082.
5. GSC 126083.

Figs. 6–10. *Neocolonograptus transgrediens* (Perner, 1899); Abandon Bay, northern Cornwallis Island (collection C11472).

6. GSC 126084.
7. GSC 126085.
8. GSC 126086.
9. GSC 126087.
10. GSC 126088.

Figs. 11–15. *Monograptus birchensis* Berry and Murphy, 1975; southeastern Baillie Hamilton Island (collection number C11445).

11. GSC 126089.
12. GSC 126090.
13. GSC 126091, tilted to show thecal hoods and sicula aperture.
14. GSC 126092.
15. GSC 126093.

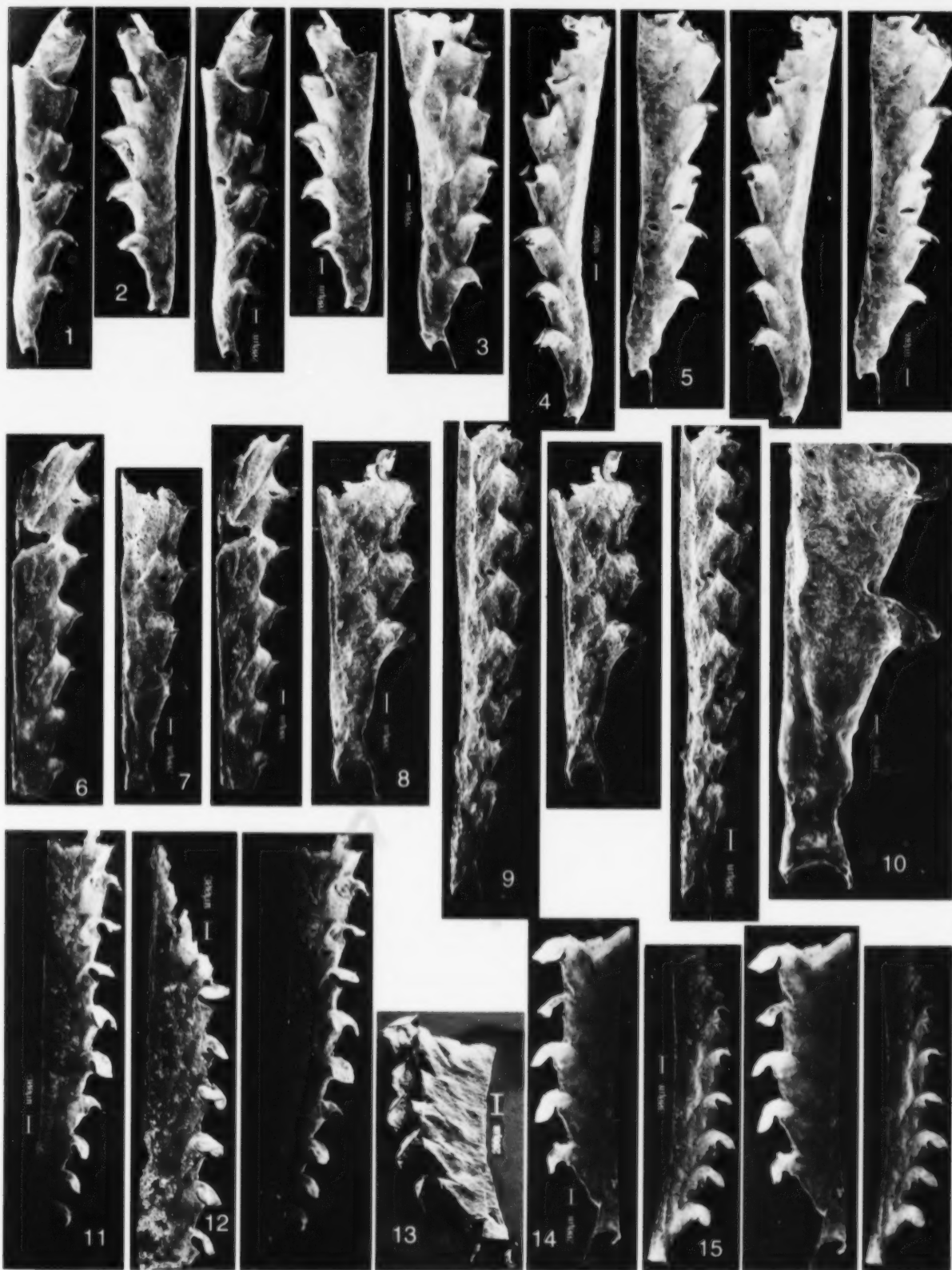


Plate 29

Figs. 1–8, 10. *Monograptus ceratus* Lenz, 1988.

1. GSC 102277, Snowblind Creek.
2. GSC 102276, Snowblind Creek.
3. GSC 126094, SB-97, D10 m.
4. GSC 126095, SBC 7A.
5. GSC 126096, SB-97, D10 m.
6. GSC 126097, SBC 7A.
7. GSC 126098, SBC 7A.
8. GSC 126099, SBC 7A.
10. GSC 126100, SB-97, D10 m.

Figs. 9, 11, 18, 19, 27. *Pristiograptus dubius* (Suess, 1851)

9. GSC 126101, SB-97, A1.5 m.
11. GSC 126102, BH2-98, 206 m.
- 18, 19. GSC 126103, BH2-98, 206 m, Fig. 18 is enlargement of thecae 1 and 2 of Fig. 19.
27. GSC 126104, SB97, A1.5 m.

Fig. 12. *Monograptus* cf. *uncinatus* Tullberg, 1883.

12. GSC 126105, SB D75 m.

Figs. 13, 14, 20–26. *Pseudomonoclimacis?* *brevicucullus* sp. nov.

13. Paratype GSC 126106, RC1-01, 22 m.
14. Paratype GSC 126107, RC1-01, 22 m, partial ventral view.
20. Holotype GSC 126108, AB2-99, 58.5 m.
21. Paratype GSC 126109, RC1-01, 22 m, distal portion.
22. Paratype GSC 126110, AB2-99, 58.5 m.
23. Paratype GSC 126111, AB2-99, 58.5 m.
- 24, 26. Paratype GSC 126112, RC1-01, 22 m, Fig. 22 tilted to see thecal interiors.
25. Paratype GSC 126113, AB2-99, 58.5 m.

Figs. 15–17. *Pseudomonoclimacis?* *bispinosus* Lenz, 1988; SB2-99, 7 m.

15. GSC 126114.
16. GSC 126115.
17. GSC 126116.

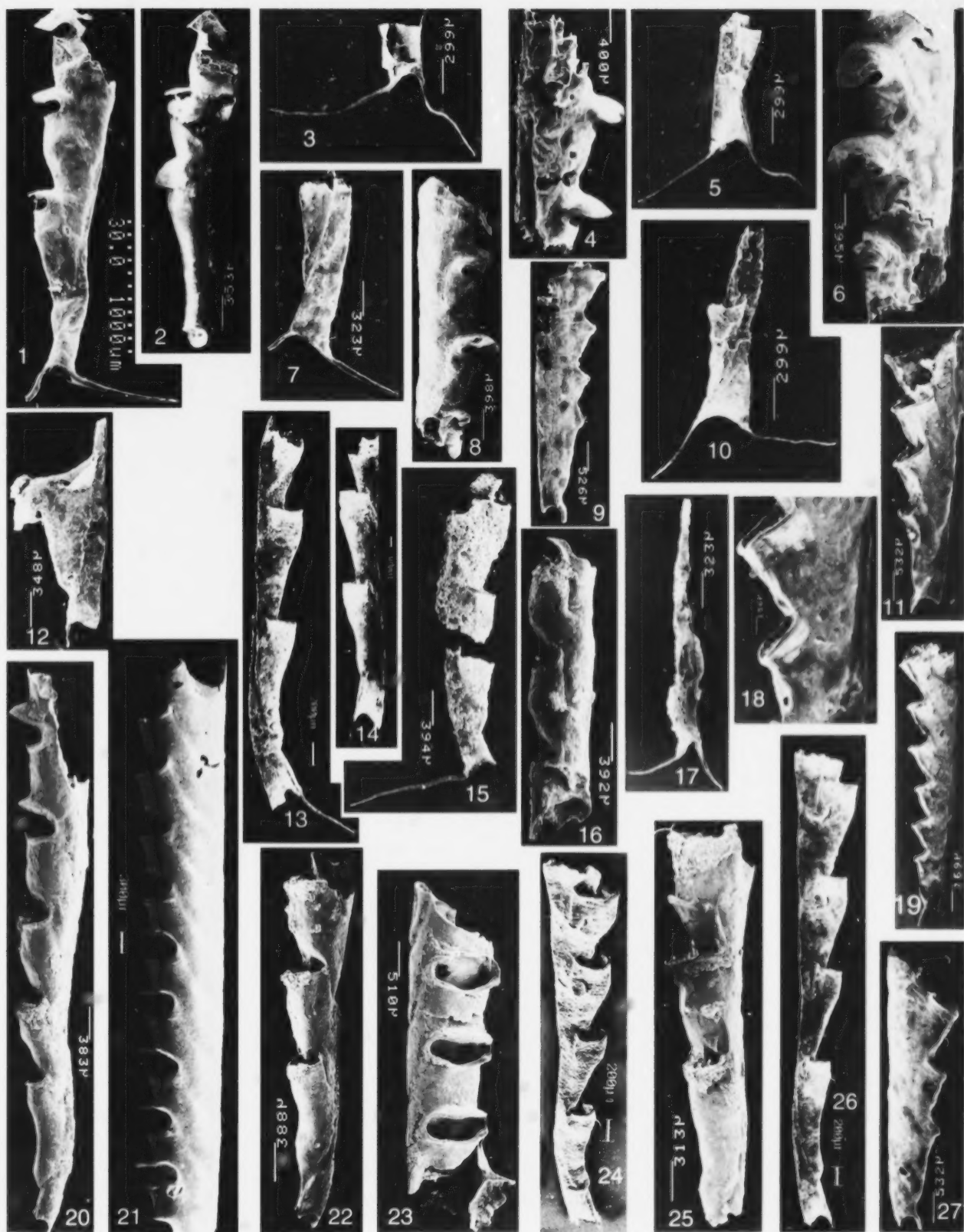


Plate 30

Figs. 1–12. *Crinitograptus operculatus* (Münch, 1938).

1. GSC 126117, SB-97, A4.5 m.
2. GSC 126118, SB-97, A4.5 m.
3. GSC 126119, SB-97, A4.5 m.
4. GSC 126120, SB-97, A4.5 m.
5. GSC 126121, AB2-99, 23 m, stereopair.
6. GSC 126122, AB2-99, 22 m, stereopair.
7. GSC 126123, AB2-99, 23 m.
8. GSC 126124, SB-97, A4.5 m.
9. GSC -126125, AB2-99, 23 m.
10. GSC 126126, AB2-99, 22 m, stereopair.
11. GSC 126127, AB2-99, 23 m.
12. GSC 126128, AB2-99, 23 m, stereopair.



Plate 31

Figs. 1-8, 10, 13, 14, 15. *Lobograptus progenitor* Urbanek, 1966.

1. GSC 126129, SBC #4, 7 m.
2. GSC 126130, SBC #4, 7 m.
3. GSC 126131, BH1-91, 57.6 m.
4. GSC 126132, SB-97, A4.5 m.
5. GSC 126133, SB-97, A4.5 m.
6. GSC 126134, SB-97, A4.5 m.
7. GSC 126135, SB-97, A4.5 m.
8. GSC 126136, MCM-91.
10. GSC 126137, SB-97, A4.5 m.
13. GSC 126138, SB-97, A4.5 m.
14. GSC 126139, AB2-98, 58.5 m.
15. GSC 126140, AB2-98, 58.5 m.

Figs. 9, 11, 12. *Lobograptus* sp.

9. GSC 126141, MCM-91.
11. GSC 126142, MCM-91.
12. GSC 126143, BH1-91, 57.6 m.

Fig. 16. ?*Neodiversograptus* cf. *beklemishevi* Urbanek, 1963.

16. GSC 126144, AB2-99, 58.5 m.

Figs. 17-25. *Bohemograptus bohemicus tenuis* (Bouček, 1936).

17. GSC 126145, MCM-91.
18. GSC 126146, MCM-91.
19. GSC 126147, BH2-98, 180 m.
20. GSC 126148, MCM-91.
21. GSC 126149, MCM-91.
22. GSC 126150, MCM-91.
23. GSC 126151, BH2-98, 180 m.
24. GSC 126152, MCM-91.
25. GSC 126153, BH2-98, 180 m.

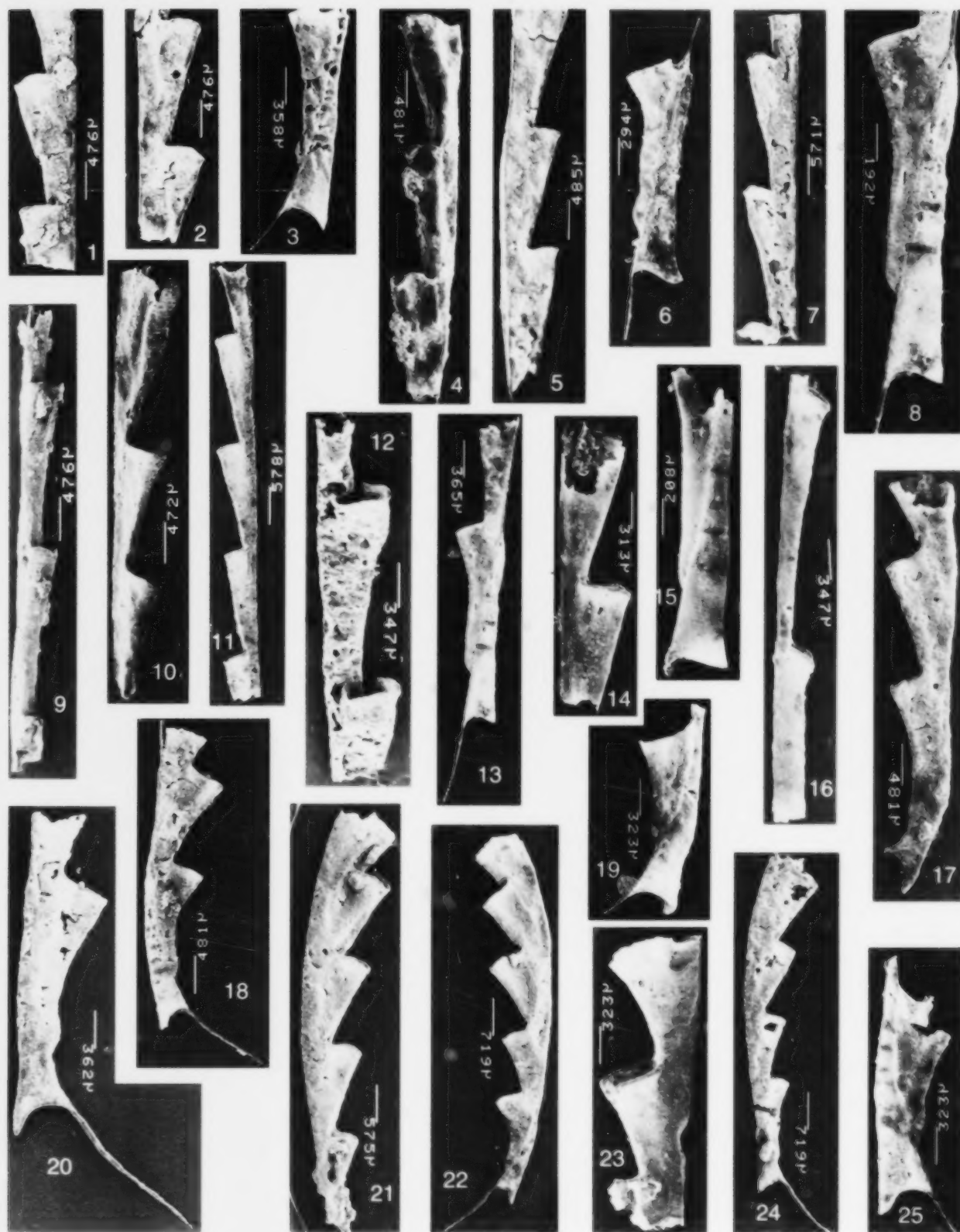


Plate 32

Figs. 1, 2. *Lobograptus cf. parascanicus* (Kühne, 1955).

1. GSC 126154, SB-97 D2, stereopair.
2. GSC 126155, SB-97 D2, stereopair.

Figs. 3, 4. *Lobograptus cf. parascanicus* (Kühne, 1955), or *Linograptus* sp.

3. GSC 126156, SB-97 D2, stereopair.
4. GSC 126157, SB-97 D2.

Figs. 5–12. *Lobograptus scanicus* (Tullberg, 1883); AB2-99, 63 m.

5. GSC 126158, stereopair.
6. GSC 126159, stereopair.
7. GSC 126160, stereopair.
8. GSC 126161.
9. GSC 126162, stereopair.
10. GSC 126163, stereopair.
11. GSC 126164, stereopair.
12. GSC 126165.



Plate 33

Figs. 1–3, 9, 10, 17. *Pseudomonoclimacis dalejensis rectus* n. subsp.

1. Paratype GSC 126166, SB-97 D1.
2. Holotype GSC 126167, SB-97 D1.
3. Paratype GSC 126168, SB-97, A1.5 m.
9. Paratype GSC 126169, SB-97 D1.
10. Paratype GSC 126170, SB-97 D1.
17. Paratype GSC 126171, SB-97 A1.5.

Figs. 4–8, 11–15, 22, 23. *Pseudomonoclimacis dalejensis dalejensis* (Bouček, 1936) (delicate form).

4. GSC 126172, SB-97, A1.5 m.
5. GSC 126173, MCM-91 A.
6. GSC 126174, SB-97, A1.5 m.
7. GSC 126175, SBC 97, A1.5 m.
8. GSC 126176, SB-97, A1.5 m.
11. GSC 126177, MCM-91.
12. GSC 126178, MCM-91.
13. GSC 126179, SB D-10 m.
14. GSC 126180, SB-97 A1.5 m.
15. GSC 126181, SB D-10 m.
22. GSC 126182, SB D-10 m.
23. GSC 126183, SB D-10 m.

Figs. 16, 18–21, 24–29. *Pseudomonoclimacis dalejensis dalejensis* (Bouček, 1936) (robust form).

16. GSC 126184, AB2-99, 63.
18. GSC 126185, AB2-99, 63 m.
19. GSC 126186, RC1-01, 17.5 m.
20. GSC 126187, AB2-99, 63 m.
21. GSC 126188, AB2-99, 63 m.
24. GSC 126189, BH2-98, 198 m.
25. GSC 126190, BH2-98, 198 m.
26. GSC 126191, BH2-98, 198 m.
27. GSC 126192, BH2-98, 198 m.
28. GSC 126193, BH2-98, 198 m, stereopair.
29. GSC 126194, AB2-99, 63 m.



Plate 34

Figs. 1–7. *Pristiograptus fragmentalis* Bouček, 1936.

1. GSC 126195, BH2-98, 92 m, stereopair.
2. GSC 126196, BH2-98, 92 m.
3. GSC 126197, BH1-91, 15 m.
4. GSC 126198, BH2-98, 92 m.
5. GSC 126199, SB-97 D75 m.
6. GSC 126200, BH2-98, 92 m.
7. GSC 126201, BH2-98, 92 m.

Figs. 8–11, 17–19. *Neocolonograptus ultimus* (Perner, 1899); BH2-98, 492 m.

8. GSC 126202, stereopair.
9. GSC 126203, stereopair.
10. GSC 126204.
11. GSC 126205 stereopair.
17. GSC 126206 stereopair.
18. GSC 126207 stereopair.
19. GSC 126208.

Figs. 12–16, 20–23. *Neocolonograptus parultimus* (Jaeger, 1975), BH2-98, 492 m.

12. GSC 126209.
13. GSC 126210.
14. GSC 126211.
15. GSC 126212.
16. GSC 126213, stereopair.
20. GSC 126214, stereopair.
21. GSC 126215.
22. GSC 126216, stereopair.
23. GSC 126217.

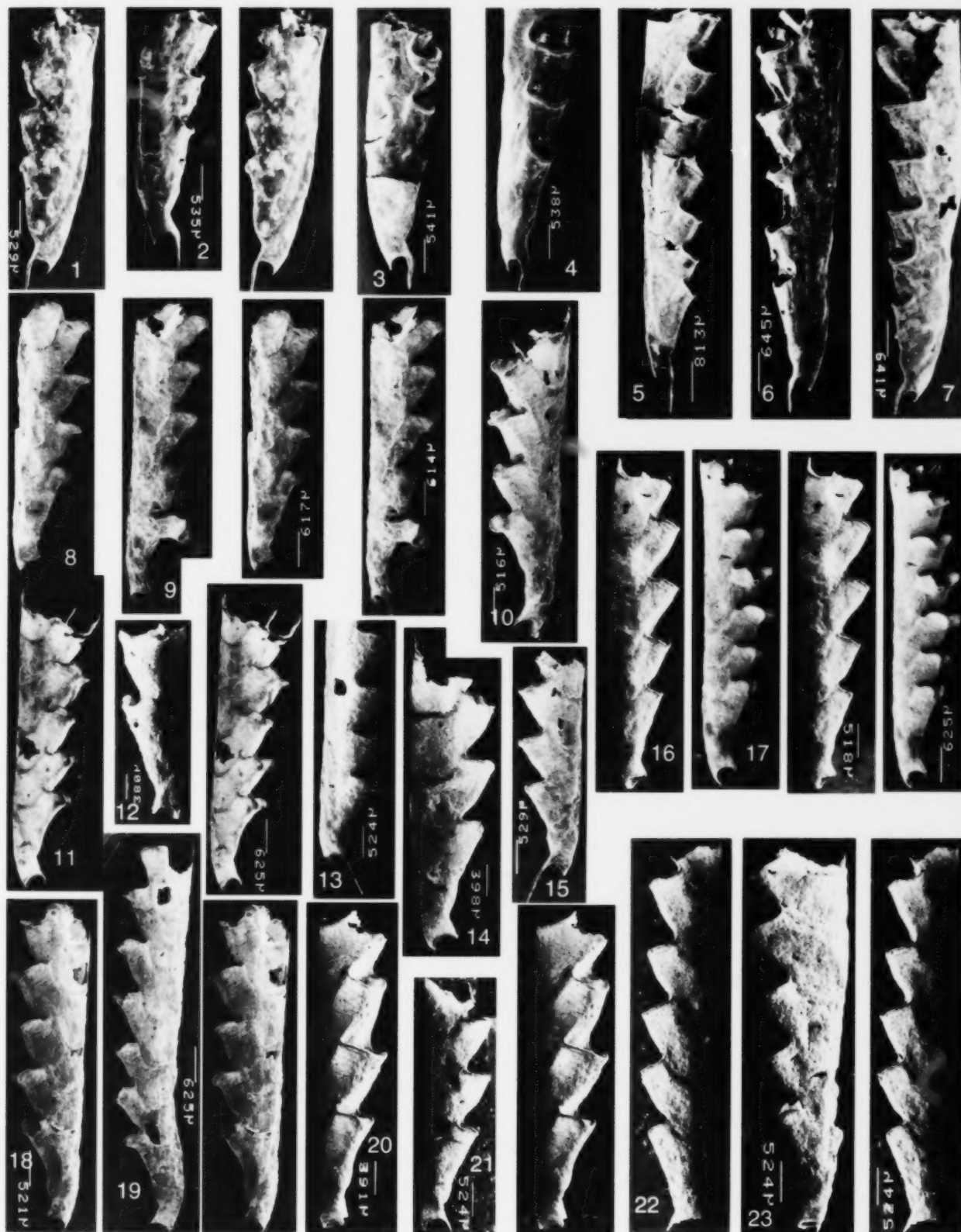


Plate 35

Figs. 1–5, 7. *Colonograptus colonus heathcotenensis* Rickards and Sandford, 1998 (vertical lines are 1 mm).

1. GSC 126218, TW 138–148 m, $\times 5$.
2. GSC 126219, TW 138–148 m, $\times 5$.
3. GSC 126220, TW 138–148 m, $\times 5$.
4. GSC 126221, CP 1590' (484.6 m), $\times 6$.
5. GSC 126222, TWW 35 m, $\times 6$.
7. GSC 126223, TWW 35 m, $\times 5$.

Figs. 6, 10, 12–15. *Crinitograptus cf. operculatus* (Kühne, 1955).

6. GSC 126224, GP 56.5 m, $\times 12$.
10. GSC 126225, GP 56.5 m, $\times 15$.
12. GSC 126226, CP 2400' (731.5 m), enlargement of Fig. 15, $\times 15$.
13. GSC 126224, GP 56.5 m, $\times 6$.
14. GSC 126227, CP 2400' (731.5 m), $\times 6$.
15. GSC 126226, CP 2400' (731.5 m), $\times 6$.

Figs. 8, 9, 11. *Saetograptus varians* (Wood, 1900) (all $\times 10$).

8. GSC 126228, GP 10.5 m.
9. GSC 126229, HH 60 m.
11. GSC 126230, HH 61.5 m.

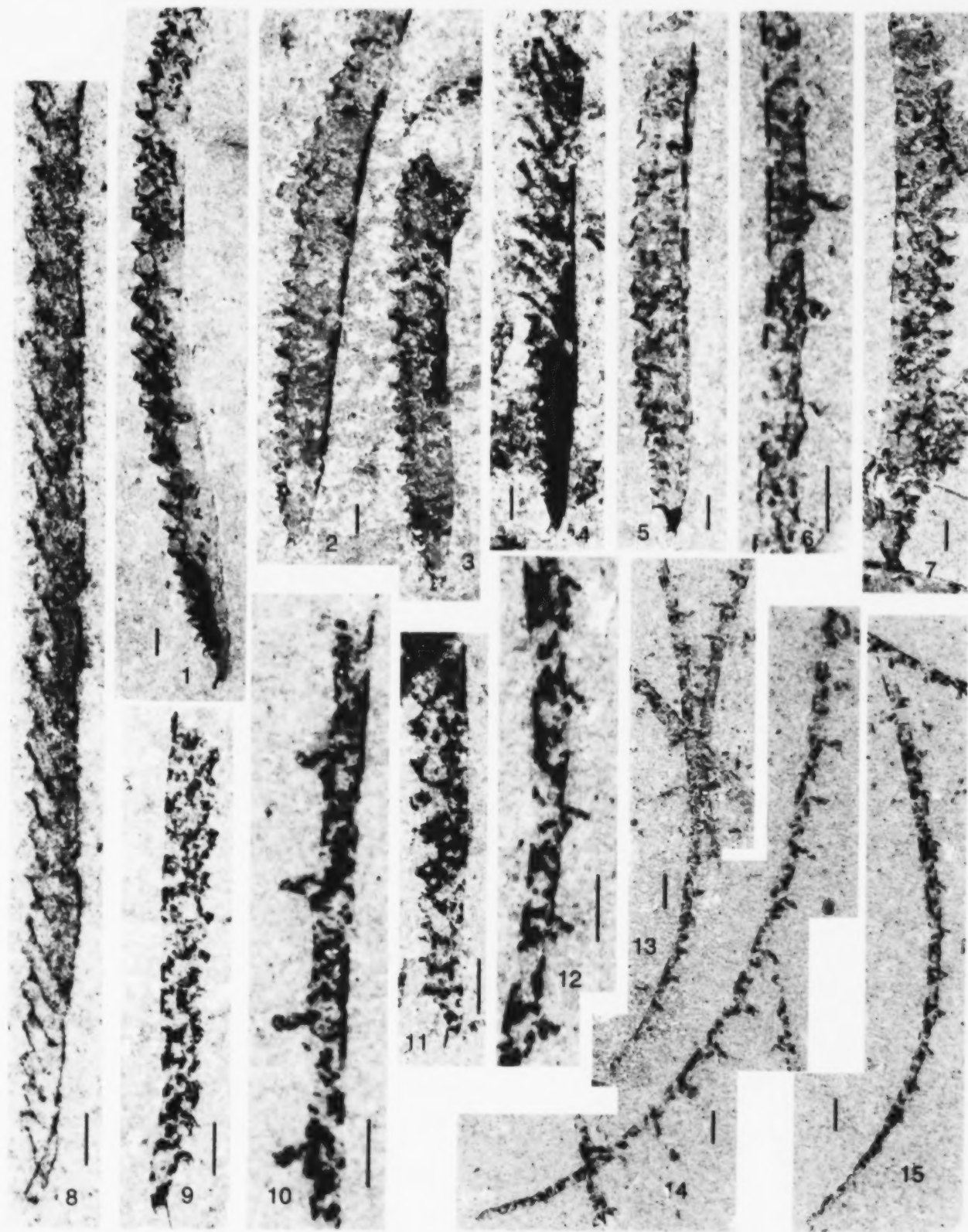




Plate 36

Figs. 1–5. *Lobograptus progenitor* Urbanek, 1966 (vertical lines are 1 mm).

1. GSC 126231, TWN 19.5 m, $\times 5$.
2. GSC 126232, TWW 16.5 m, enlargement of Fig. 5, $\times 10$.
3. GSC 126231, TWN 19.5 m, enlargement of Fig. 1, $\times 10$.
4. GSC 126233, SBC 4, 5–8 m, $\times 5$.
5. GSC 126232, TWW 16.5 m, $\times 5$.

Figs. 6, 7. *Linograptus?* sp.; $\times 11$.

6. GSC 126234, TWW 15.1 m.
7. GSC 126235, GP 29 m.

Figs. 8, 9. *Linograptus posthumus tenuis* Jaeger, 1959.

8. GSC 126236, CP 2175' (663.2 m), $\times 8$.
9. GSC 126237, SJF 298 m, $\times 10$.

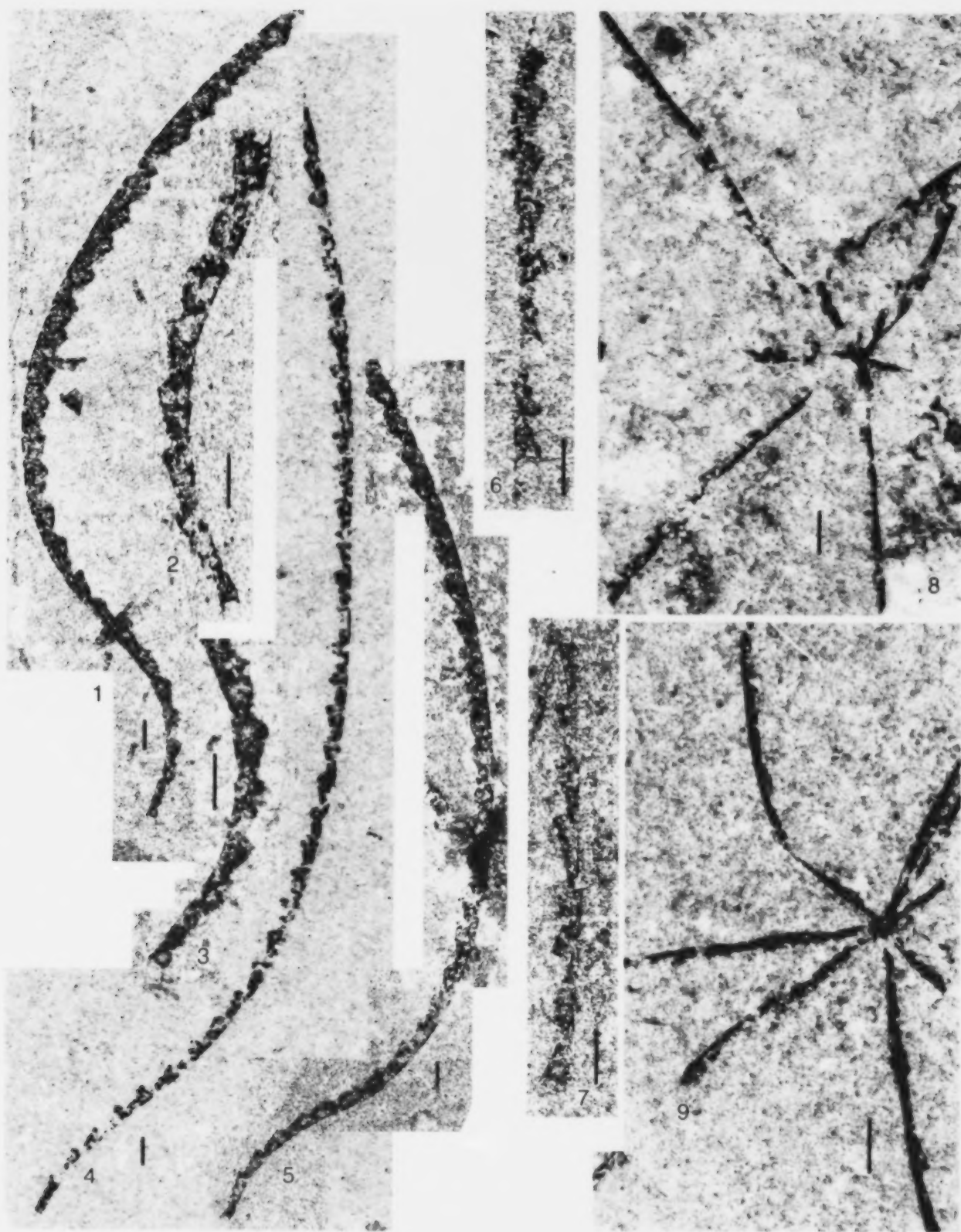




Plate 37

Figs. 1–5, 7. *Bohemograptus bohemicus bohemicus* (Barrande, 1850) (all $\times 5$) (vertical lines are 1 mm).

1. GSC 126238, TC 3B.
2. GSC 126239, MMI 122.5 m.
3. GSC 126240, HH 93 m.
4. GSC 126241, TC 3B.
5. GSC 126242, MMI 122.5 m.
- 7.? GSC 126243, TC #2 (possibly *B. praecornutus*).

Figs. 6, 8, 14. *Bohemograptus bohemicus tenuis* (Bouček, 1936) ($\times 5$).

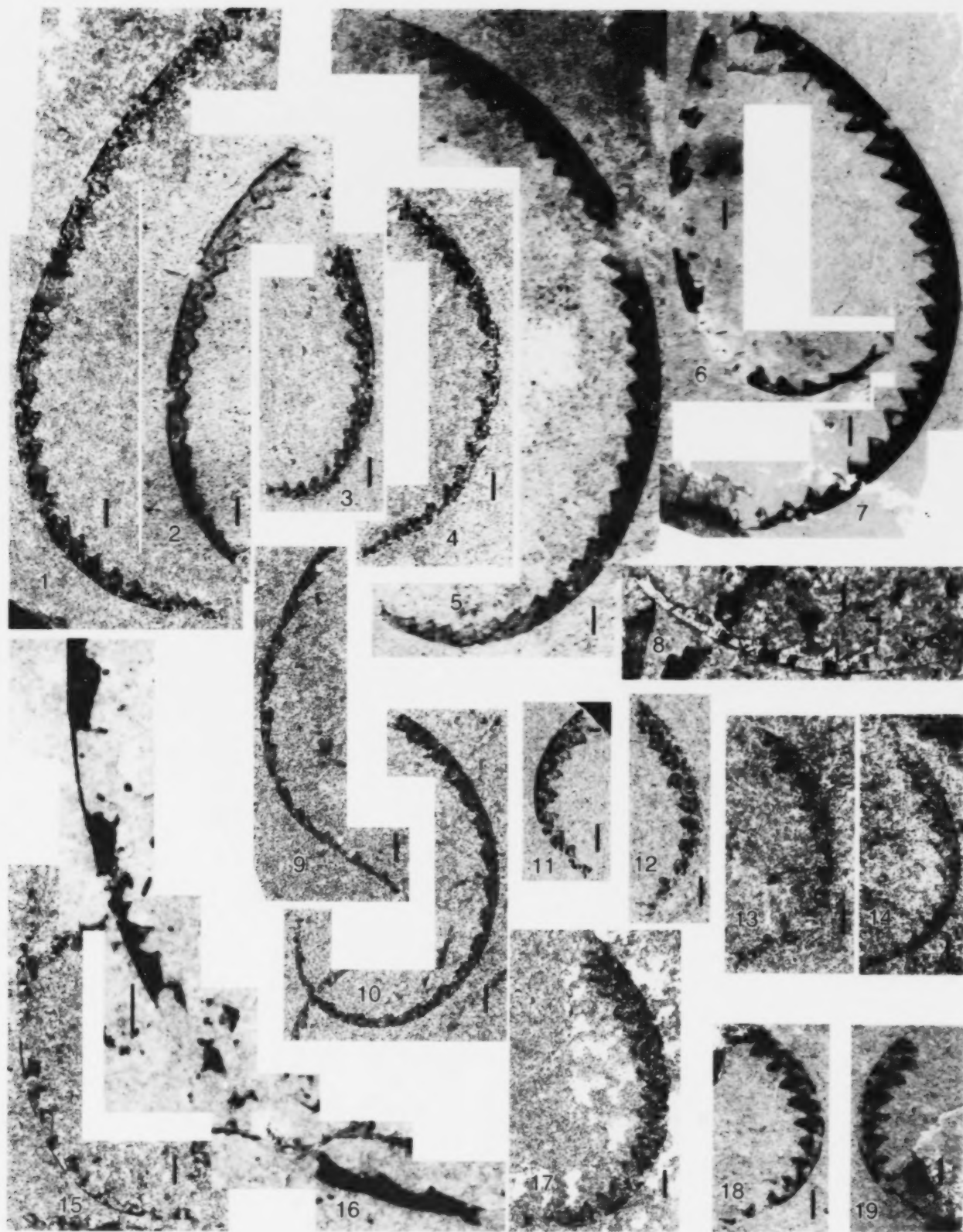
6. GSC 126244, SB D75 m.
8. GSC 126245, SBC 7C.
14. GSC 126246, SJF 290 m.

Figs. 9, 10, 15, 16. *Bohemograptus garratti* Rickards, Davidson, and Banks, 1993.

9. GSC 126247, TC 3, $\times 5$.
10. GSC 126248, TC 3, $\times 5$.
15. GSC 126249, SJF 290 m, $\times 5$.
16. GSC 126250, SJF 290 m, $\times 10$.

Figs. 11–13, 17–19. *Bohemograptus praecornutus* Urbanek, 1970 (all $\times 5$).

11. GSC 126251, SJF 298 m.
12. GSC 126252, SJF 298 m.
13. GSC 126253, SJF02, 148 m.
17. GSC 126254, GP 48 m.
18. GSC 126255, IB 21 m.
19. GSC 126256, IB 21 m.



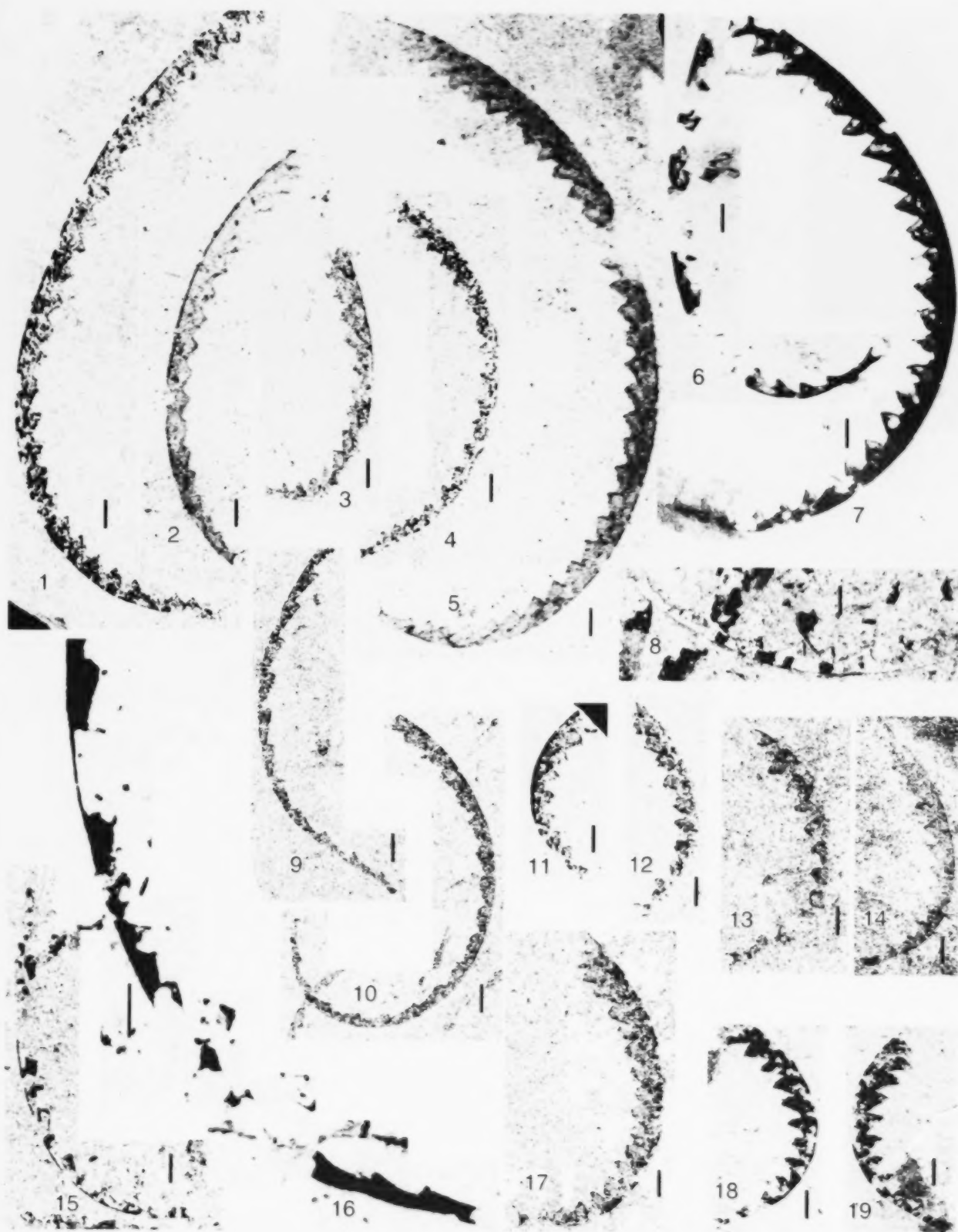


Plate 38

Fig. 1. *Monograptus bouceki* Příbyl, 1940 (vertical lines are 1 mm).

1. GSC 126257, SF 100 m, x6.

Figs. 2, 11. *Saetograptus linearis* (Bouček, 1936) (x6).

2. GSC 126258, AB-99, 116 m.
11. GSC 126259, AB-99, 116 m.

Figs. 3–7. *Monograptus bessobaensis* Koren', 1986 (all x6).

3. GSC 126260, GP 57.5 m.
4. GSC 126261, GP 57.5 m.
5. GSC 126262, TC #21.
6. GSC 126263, TWN 35 m.
7. GSC 126264, TWN 35 m.

Figs. 8–10, 16–19. *Monograptus ceratus* Lenz, 1988

8. GSC 126265, SB-F 300 m, x6.
9. GSC 126266, SBC 7C, x10.
10. GSC 126267, SJF 191 m, x6.
16. GSC 126268, TC 5, x6.
17. GSC 126269, SB-D 75 m, x6.
18. GSC 126270, SB-F 320 m, x6.
19. GSC 126271, SB-F 320 m, x6.

Figs. 12–15. *Monograptus uncinatus* Tullberg, 1883?; TC 3.

12. GSC 126272, x8.
13. GSC 126273, x6.
14. GSC 126274, x6.
15. GSC 126275, x6.

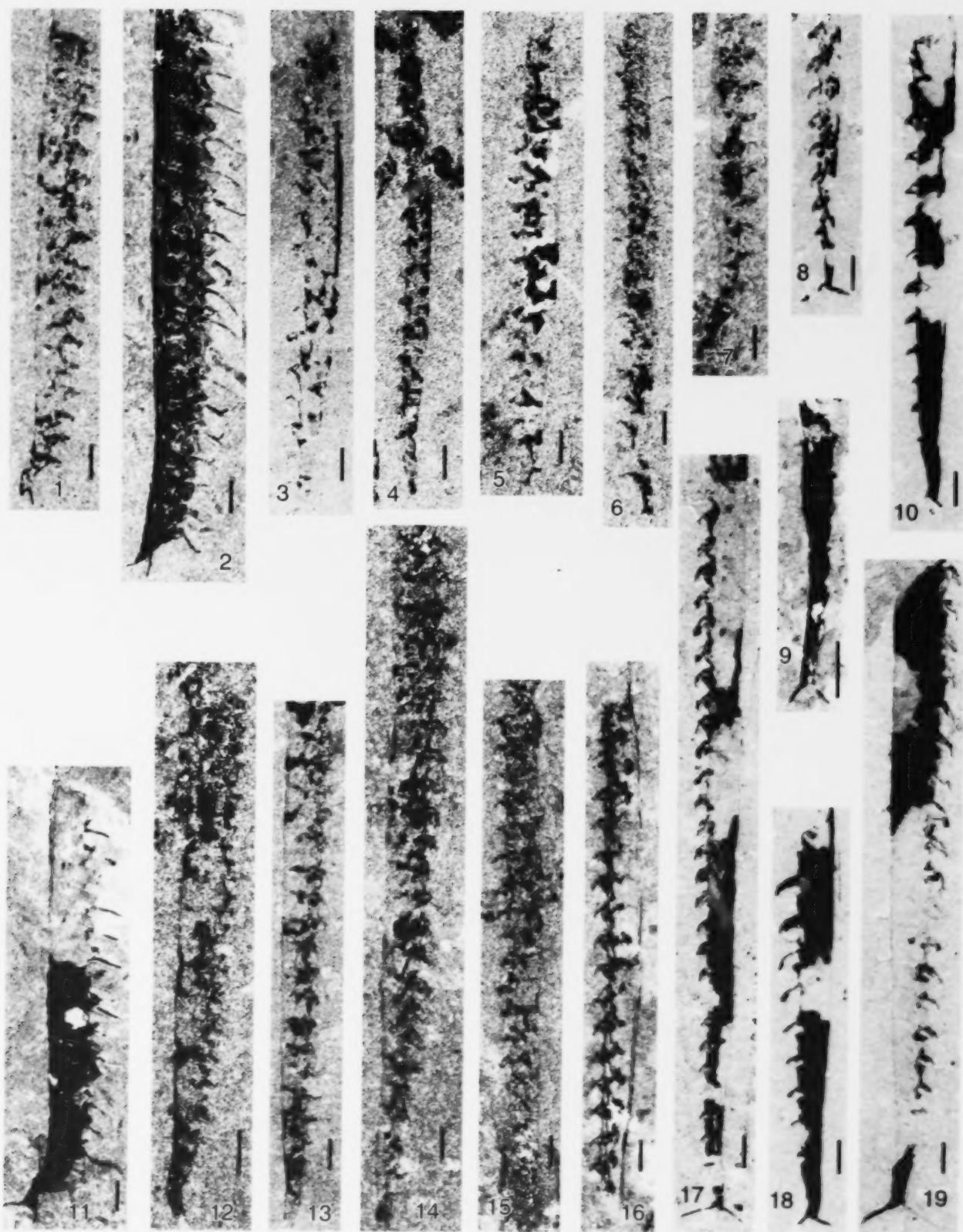




Plate 39

Figs. 1–8. *Monograptus birchensis* Berry and Murphy, 1975 (vertical lines are 1 mm).

1. GSC 126276, SJF-2, $\times 6$.
2. GSC 126277, GP 130 m, $\times 8$.
3. GSC 126278, SF 410 m, $\times 6$.
4. GSC 126279, HH 204 m, $\times 6$.
5. GSC 126280, HH 198 m, $\times 10$.
6. GSC 126281, SJF-2, $\times 6$.
7. GSC 126282, HH 189 m, $\times 6$.
8. GSC 126283, HH 198 m, $\times 6$.

Figs. 9–12. *Monograptus microdon curvatus* subsp. nov.; locality C146446 ($\times 10$).

9. Paratype GSC126284.
10. Paratype GSC 126285.
11. Holotype GSC 126286.
12. Paratype GSC 126287.

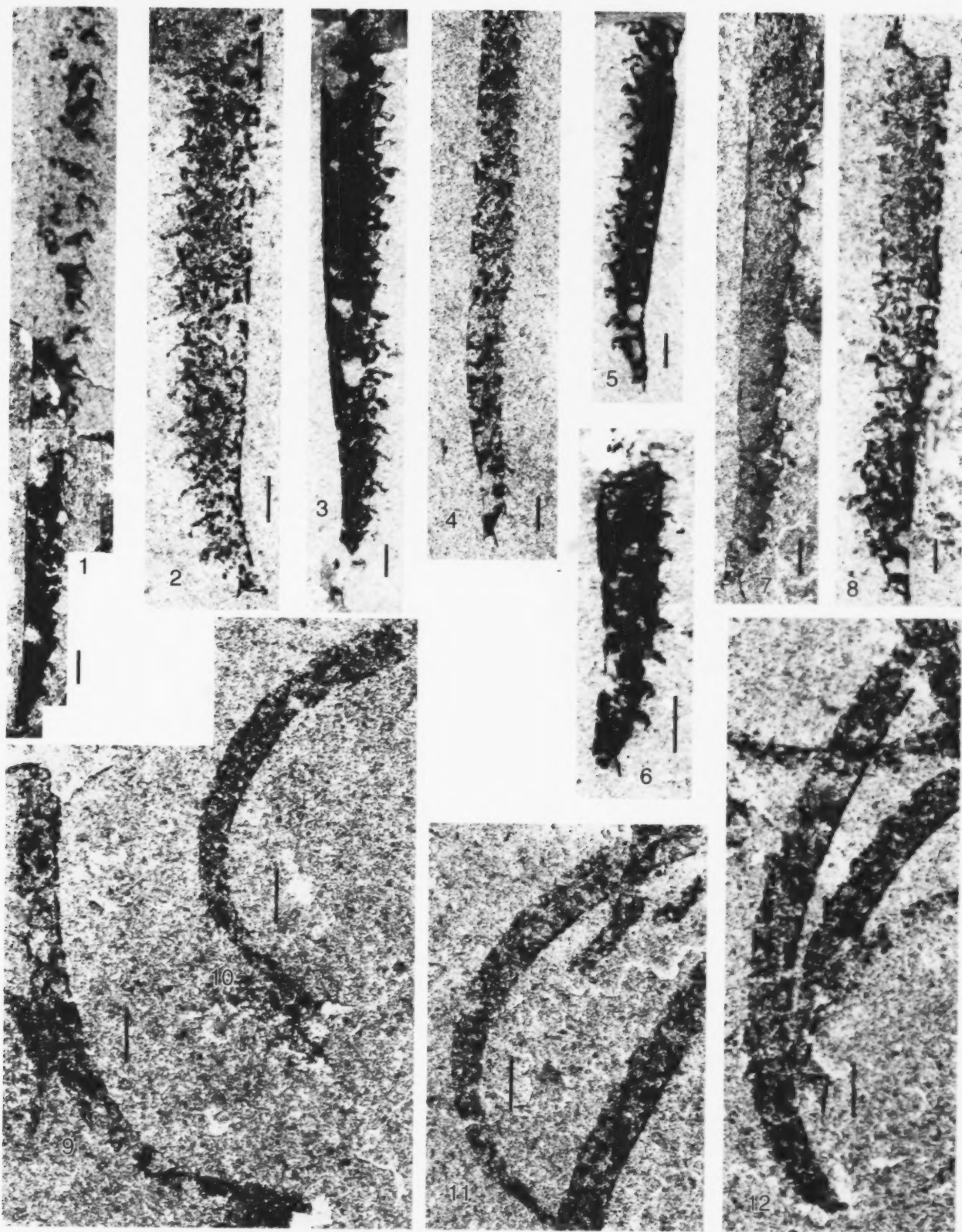




Plate 40

Figs. 1, 2. *Lobograptus parascanicus* (Kühne, 1955); locality C198514 ($\times 10$) (vertical lines are 1 mm).

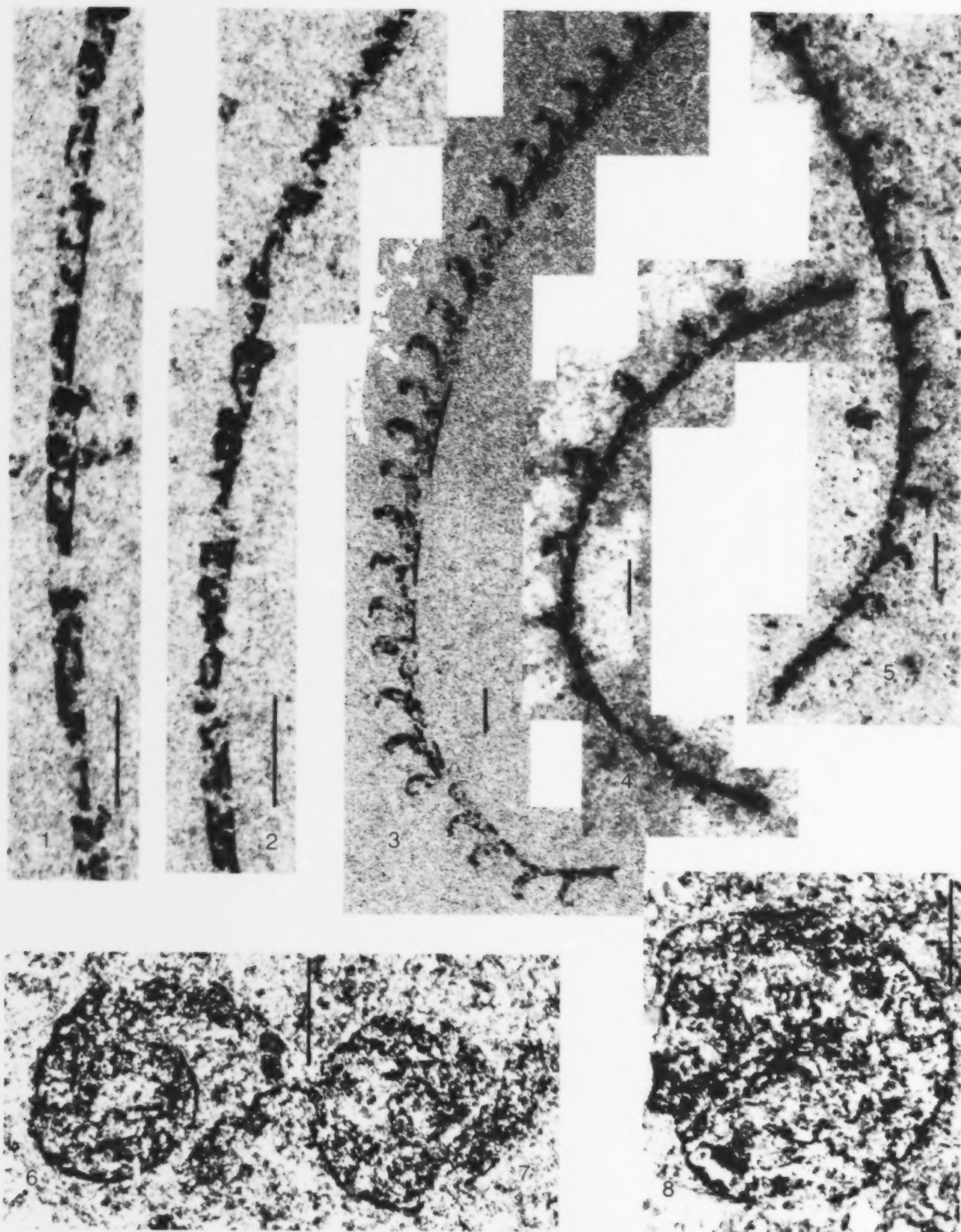
1. GSC 126288.
2. GSC 126289.

Figs. 3–5. *Formosograptus formosus* (Bouček, 1931)

3. GSC 126290, locality C207032, $\times 8$.
4. GSC 126291, de Freitas #9-3, $\times 10$.
5. GSC 126292, CP 2260' (688.8 m), $\times 10$.

Figs. 6–8. *Bohemograptus? helicoides* (Jackson and Lenz, 1972); locality C199111 ($\times 20$).

6. GSC 126293.
7. GSC 126294.
8. GSC 126295.



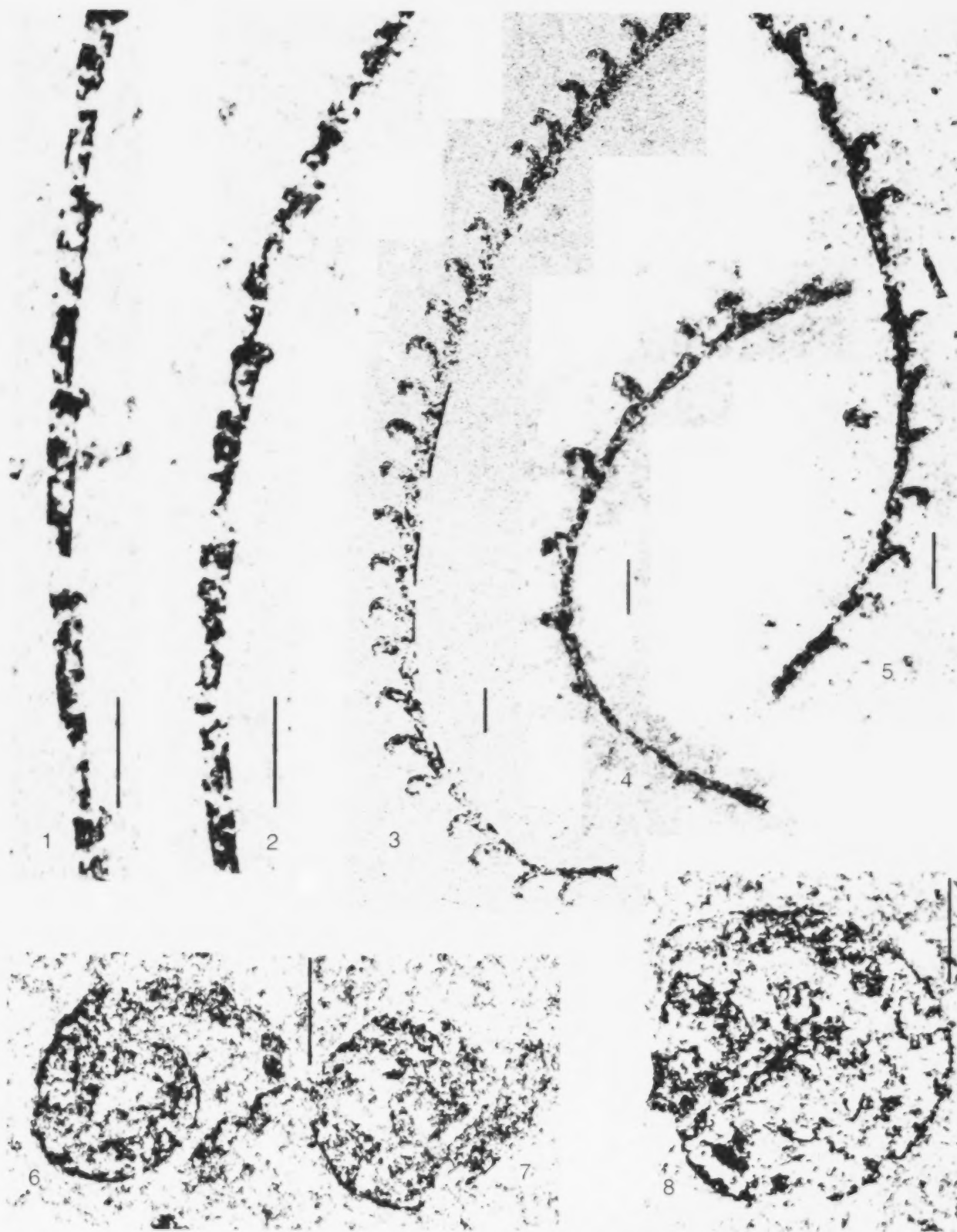


Plate 41

Figs. 1, 2. *Pristiograptus dubius* (Suess, 1851); GP 18 m (×8) (vertical lines are 1 mm).

1. GSC 126296.
2. GSC 126297.

Figs. 3, 15. *Pseudomonoclimacis dalejensis rectus* subsp. nov.; AB4-99, 116 m.

3. Paratype GSC 126298, ×6.
15. Paratype GSC 126399, ×8.

Figs. 4–7. *Neocolonograptus? norfordi* (Lenz and Jackson, 1971); de Freitas #5-8 (×10).

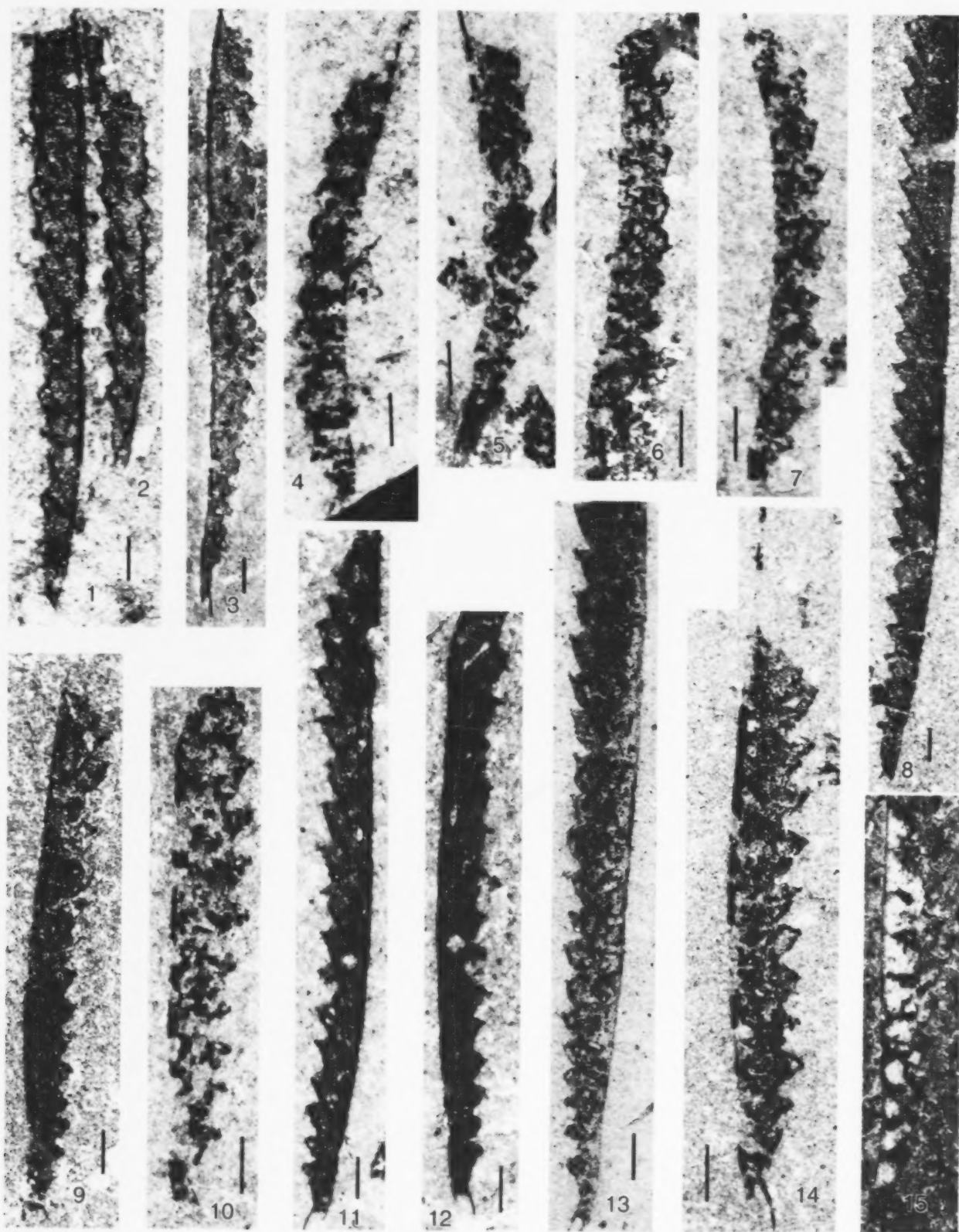
4. GSC 126300.
5. GSC 126301.
6. GSC 126302.
7. GSC 126303.

Figs. 8–12, 14. *Neocolonograptus parultimus* (Jaeger, 1975).

8. GSC 126304, locality C198699, ×6.
9. GSC 126305, locality C198699, ×8.
10. GSC 126306, TC 16, ×10.
11. GSC 126307, locality C207017 (part), ×8.
12. GSC 126308, locality C202017 (counterpart), ×8.
14. GSC 126309, HH 132 m, 10.

Fig. 13. *Neocolonograptus ultimus* (Perner, 1899)?

13. GSC 126310, TC 17, ×8.



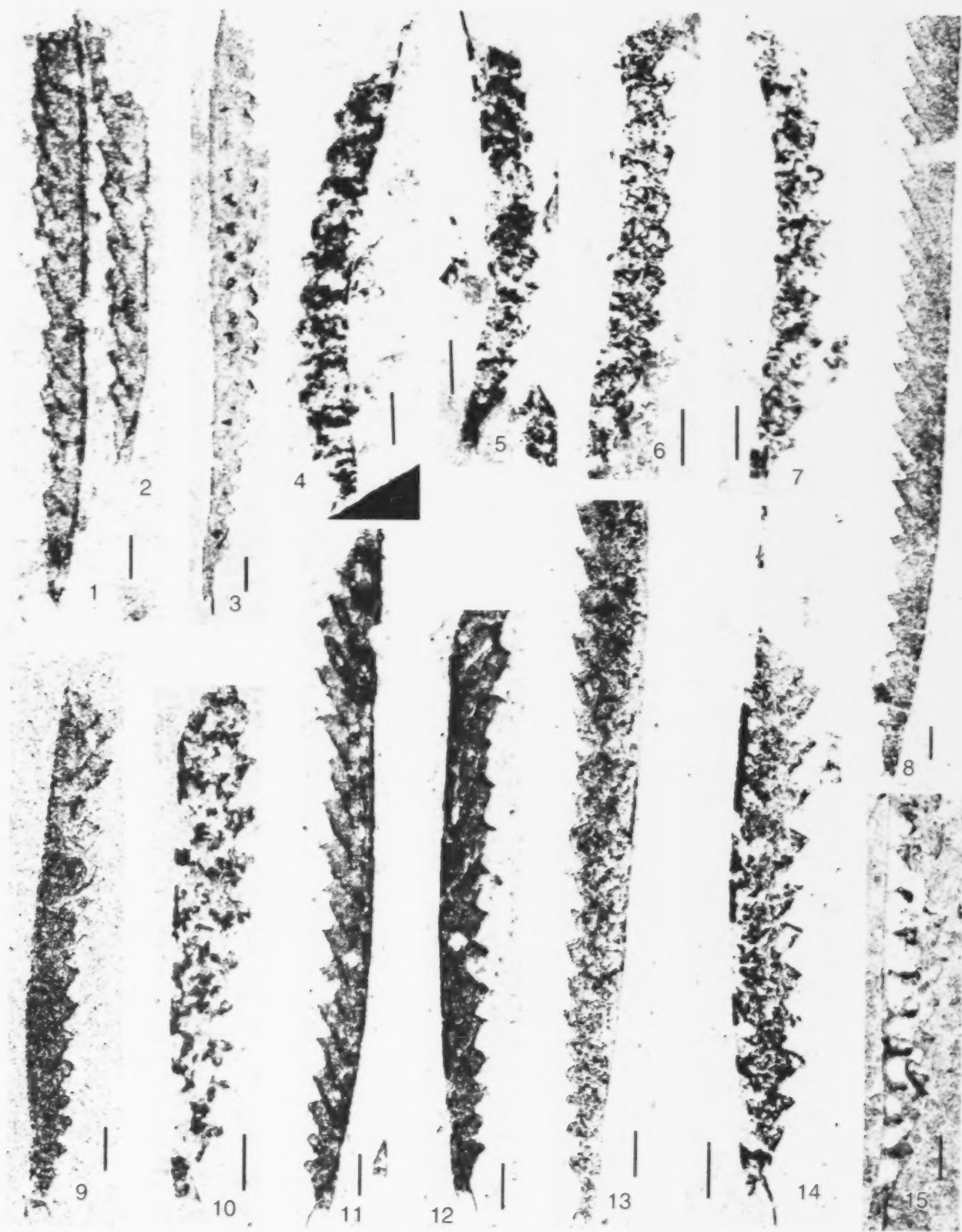


Plate 42

Figs. 1–3, 13. *Neocolonograptus branikensis* (Jaeger, 1986) ($\times 10$) (vertical lines are 1 mm).

1. GSC 126311, TC 19.
2. GSC 126312, HH 126 m.
3. GSC 126313, TWN 35 m
13. GSC 126314, SF 38 m.

Figs. 4–7, 14, 15. *Neocolonograptus ultimus* (Perner, 1899).

4. GSC 126315, HH 168 m, $\times 6$.
5. GSC 126316, HH 139.5 m, $\times 8$.
6. GSC 126317, HH 139.5 m, $\times 8$.
7. GSC 126318, TC 21, $\times 8$.
14. GSC 126319, HH 139.5 m, $\times 5$.
15. GSC 126320, locality C198699, $\times 5$.

Figs. 8–12. *Neocolonograptus transgrediens* (Perner, 1899).

8. GSC 126321, locality C146443, $\times 12$.
9. GSC 126322, TC 33, $\times 8$.
10. GSC 126323, locality C198698, $\times 8$.
11. GSC 126324, TC 26, $\times 9$.
12. GSC 126325, SF 264 m, $\times 9$.

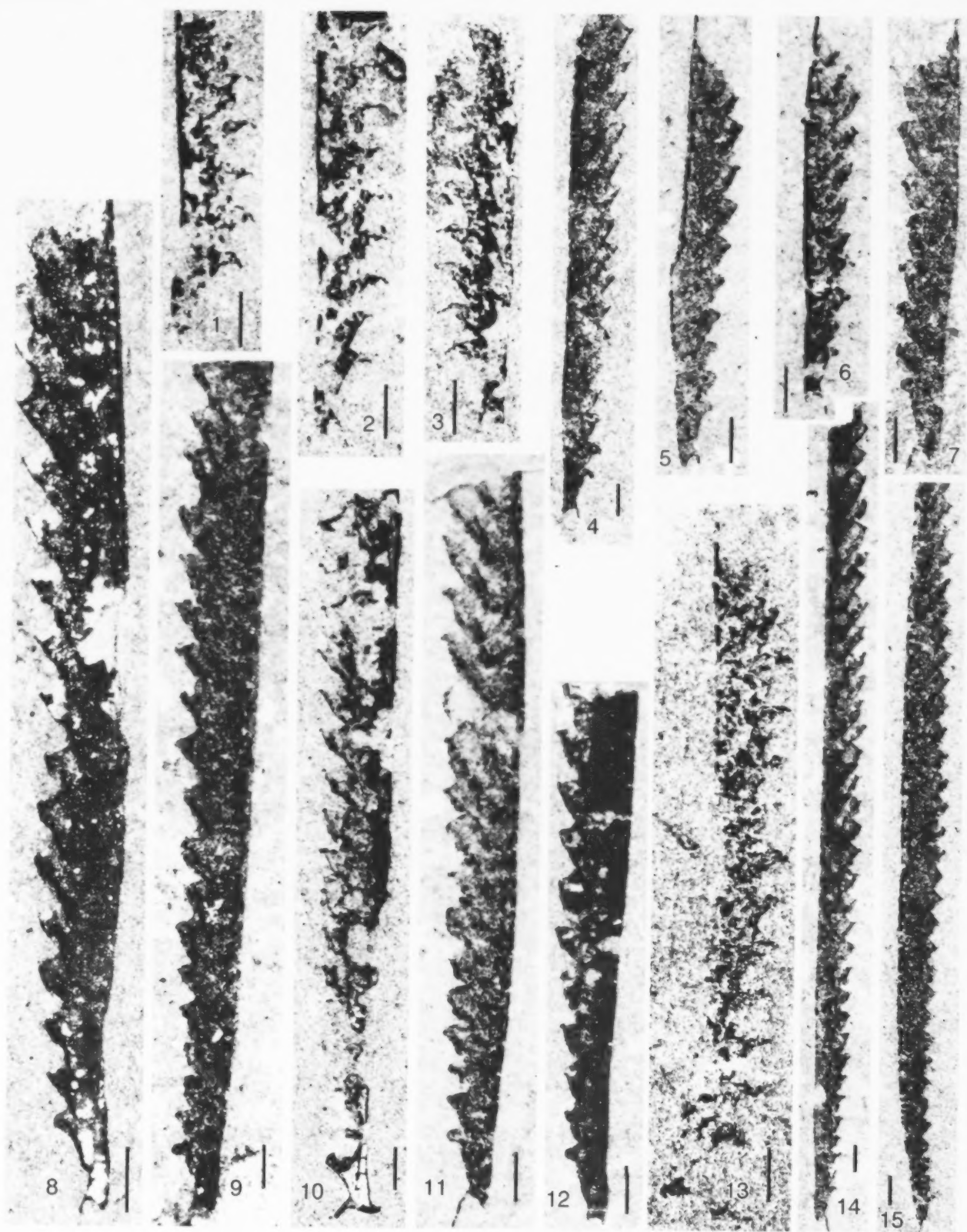




Plate 43

Figs. 1–6. *Lobograptus progenitor* Urbanek, 1966 (all $\times 6$).

1. GSC 126326, BH2-99, 23.5 m.
2. GSC 126231, TWW 19.5 m.
3. GSC 126327, MMI 122.5 m.
4. GSC 126232, TWW 16.5 m.
5. GSC 126328, HH 60 m.
6. GSC 126233, SBC4, 5–8 m.

Figs. 7–10. *Saetograptus varians* (Wood, 1900).

7. GSC 126228, GP 12.5 m, $\times 7.5$.
8. GSC 126229, HH 60 m, $\times 6$.
9. GSC 126329, HH 61.5 m, $\times 6$.
10. GSC 126330, HH 61.5 m, $\times 6$.

Figs. 11–14. *Linograptus?* sp. (all $\times 6$).

11. GSC 126234, TWW 15.1 m.
12. GSC 126331, GP 29 m.
13. GSC 126332, TWW 15.1 m.
14. GSC 126235, GP 29 m.

Figs. 15–19. *Bohemograptus? helicoides* (Jackson and Lenz, 1972) (all $\times 6$); locality C199111.

15. GSC 126294.
16. GSC 126333.
17. GSC 126293.
18. GSC 126295.
19. GSC 126334.

Figs. 20–25. *Crinitograptus cf. operculatus* (Münch, 1938).

20. GSC 126225, CP 2400' (731.5 m), $\times 6$.
21. GSC 126226, CP 2400' (731.5 m), $\times 6$.
22. GSC 126335, CP 2400' (731.5 m), $\times 6$.
23. GSC 126225, CP 2400' (731.5 m), enlargement of Fig. 20, $\times 12$.
24. GSC 126336, GP 56.5 m, $\times 24$.
25. GSC 126224, GP 56.5 m, $\times 12$.

Figs. 26, 27. *Lobograptus parascanicus* (Kühne, 1955).

26. GSC 126288, Cape Sir John Franklin (no collection number), $\times 6$.
27. GSC 126288, Cape Sir John Franklin (no collection number), enlargement of Fig. 26, $\times 12$.

Figs. 28–30. *Colonograptus colonus heathcotensis* (Rickards and Sandford, 1998) (all $\times 6$); TW-98, 138–148 m.

28. GSC 126222.
29. GSC 126221.
30. GSC 126218.

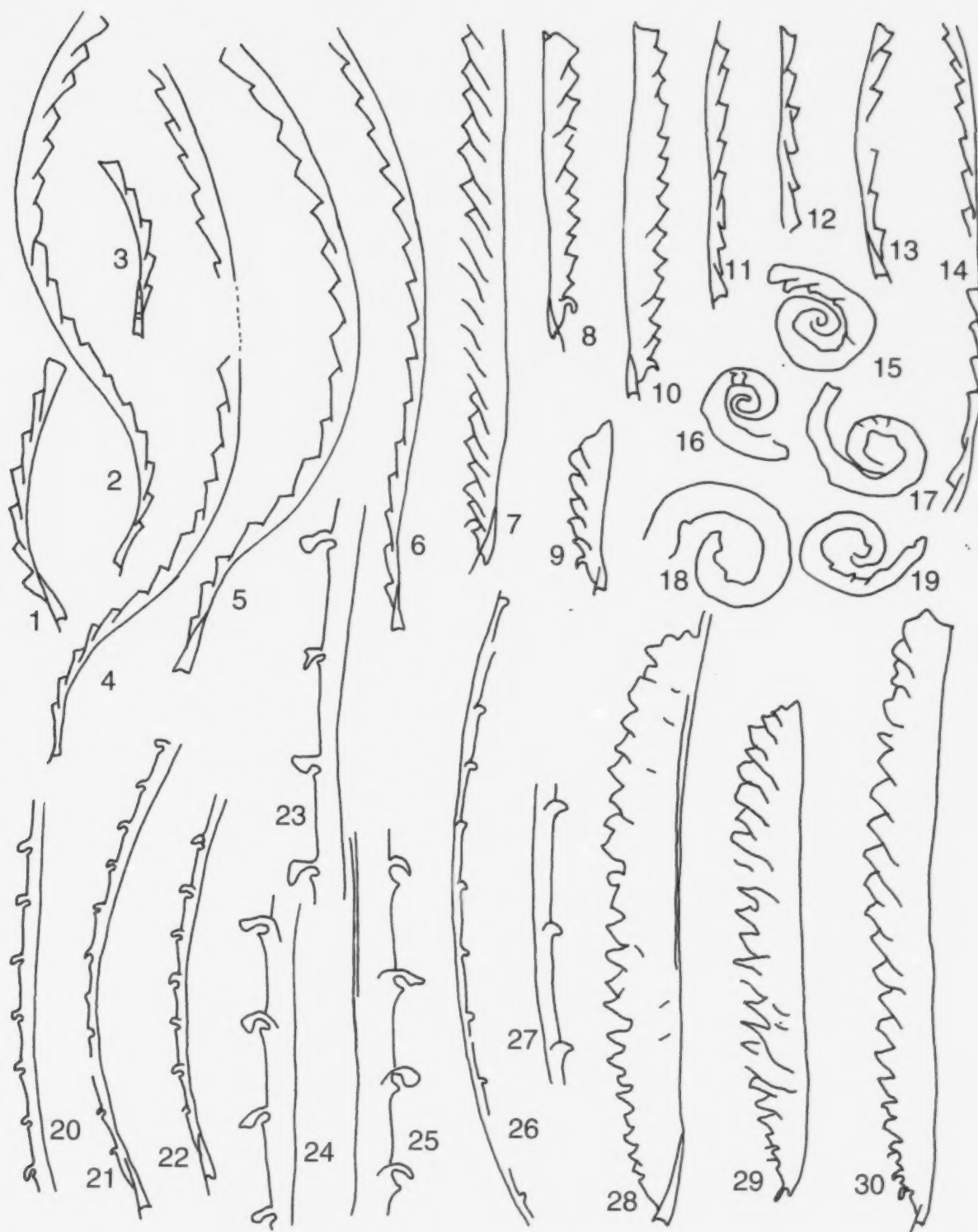


Plate 44

Figs. 1–5. *Bohemograptus bohemicus bohemicus* (Barrande, 1850) (all $\times 6$).

1. GSC 126239, MMI 122.5 m
2. GSC 126238, TC 3B.
3. GSC 126240, HH 93 m.
4. GSC 126241, TC 2.
5. GSC 126242, MMI 122.5 m.

Figs. 6–8, 14, 15. *Bohemograptus bohemicus tenuis* (Bouček, 1936).

6. GSC 126337, TC 11, $\times 6$.
7. GSC 126243, Cape Sir John Franklin (no collection number), $\times 6$.
8. GSC 126245, SBC 7C, $\times 6$.
14. GSC 126244, SB D75 m, enlargement of Fig. 15, $\times 12$.
15. GSC 126244, SB D75 m, $\times 6$.

Figs. 9–11. *Bohemograptus garratti* Rickards, Davidson, and Banks, 1993 (all $\times 6$).

9. GSC 126339, SJF 290 m.
10. GSC 126340, TC 3.
11. GSC 126248, TC 3.

Figs. 12, 16–18. *Linograptus posthumus tenuis* Jaeger, 1959 (all $\times 6$).

12. GSC 126237, TC 20.
16. GSC 126236, CP 2175' (662.9 m).
17. GSC 126341, TC 20.
18. GSC 126342, TC 29.

Figs. 13, 19–22. *Bohemograptus praecornutus* Urbanek, 1970 (all $\times 6$).

13. GSC 126256, IB 1.
19. GSC 126343, IB 1.
20. GSC 126251, SJF 298 m.
21. GSC 126252, SJF 298 m.
22. GSC 126254, GP 48 m.

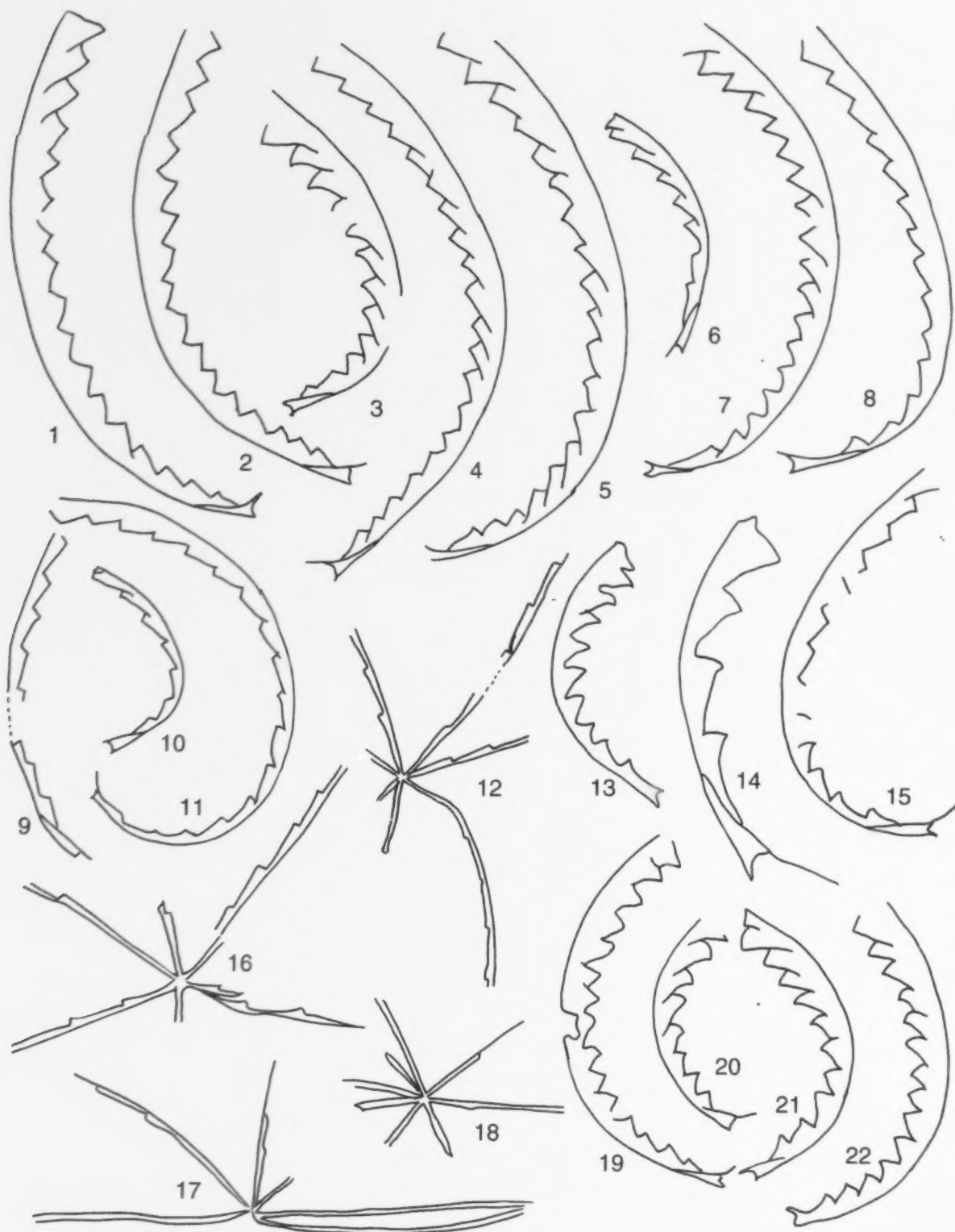


Plate 45

Figs. 1–4. *Monograptus ceratus* Lenz, 1988 (all $\times 6$).

1. GSC 126271, SB F 320 m.
2. GSC 126269, SB D 75 m.
3. GSC 126267, SB F 300 m.
4. GSC 126270, SB F 320 m.

Figs. 5. *Monograptus bouceki* Přibyl, 1940.

5. GSC 257, SF 100 m, $\times 6$.

Fig. 6. *Monograptus* cf. *bouceki* Přibyl, 1940.

6. GSC 126344, TC 21, $\times 6$.

Figs. 7–10. *Monograptus uncinatus* Tullberg, 1883? (all $\times 6$); TC 3.

7. GSC 126275.
8. GSC 126273.
9. GSC 126272.
10. GSC 126274.

Figs. 11, 12, 24–26. *Monograptus birchensis* Berry and Murphy, 1975 (all $\times 6$).

11. GSC 126277, GP 130 m.
12. GSC 126345, C198740.
24. GSC 126276, SJF 2.
25. GSC 126278, SF 410 m.
26. GSC 126346, Birch Canyon, Nevada; topotype specimen.

Figs. 13–16. *Monograptus bessobaensis* Koren', 1986 (all $\times 6$).

13. GSC 126261, GP 57.5 m.
14. GSC 126262, TWN 35 m.
15. GSC 126263, TWN 35 m.
16. GSC 126264, TWN 35 m.

Figs. 17, 19, 20. *Formosograptus formosus* (Bouček, 1931) (all $\times 6$).

17. GSC 126292, CP 2260' (688.8 m).
19. GSC 126290, locality C207032.
20. GSC 126291, de Freitas #9-3.

Figs. 18, 21–23. *Monograptus microdon curvatus* subsp. nov. (all $\times 6$); locality C146446.

18. Paratype GSC 126284.
21. Paratype GSC 126287.
22. Holotype GSC 126286.
23. Paratype GSC 126347.

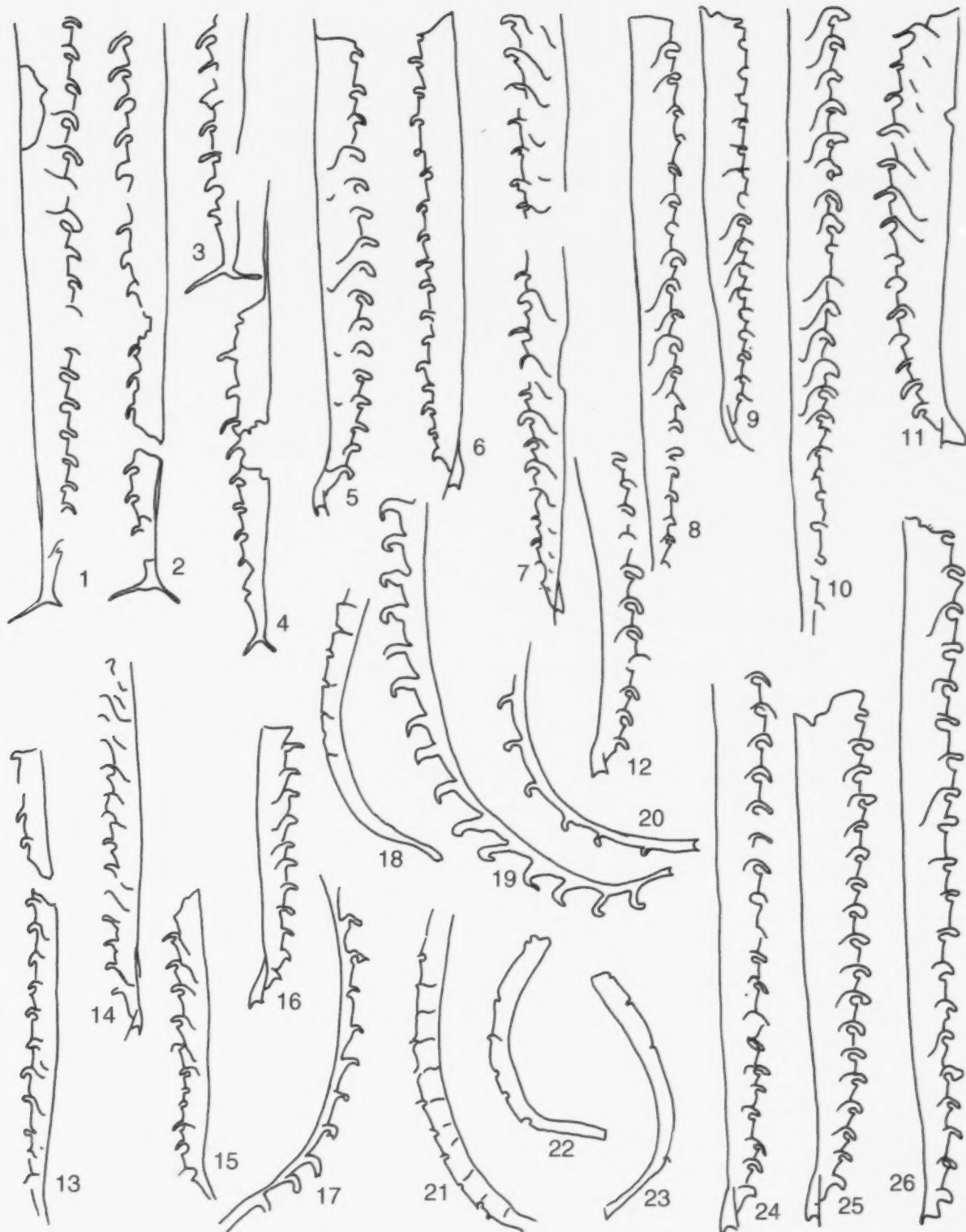


Plate 46

Figs. 1, 2. *Pristiograptus dubius* (Suess, 1851).

1. GSC 126296, GP 18 m, x6.
2. GSC 126297, GP 18 m, x6.

Figs. 3–5. *Neocolonograptus? norfordi* Lenz and Jackson, 1971 (all x6); de Freitas #5-8.

3. GSC 126301.
4. GSC 126300.
5. GSC 126303.

Figs. 6–8, 13. *Neocolonograptus parultimus* Jaeger, 1975 (all x6).

6. GSC 126307, locality C207017.
7. GSC 126308, locality C207017.
8. GSC 126304, locality C198697.
13. GSC 126305, locality C198697.

Figs. 9–12, 15, 16, 18. *Neocolonograptus? transgrediens* (Perner, 1899).

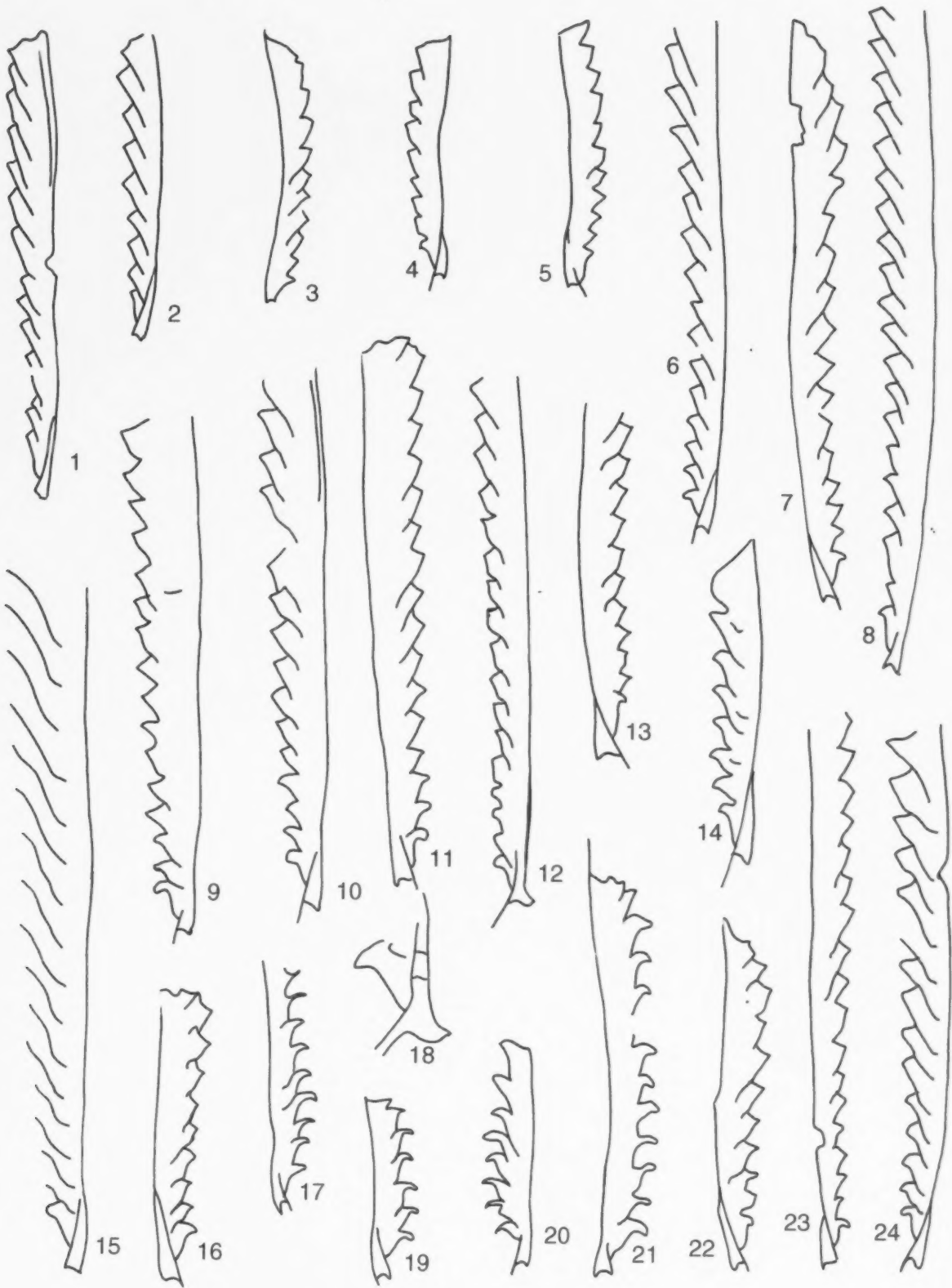
9. GSC 126322, TC 26, x6.
10. GSC 126324, TC 26, x6.
11. GSC 126348, HH 168 m, x6.
12. GSC 126323, locality C198699, x6.
15. GSC 126349, locality C207035, x6.
16. GSC 126350, SF 165 m, x6.
18. GSC 126323, locality C198699, enlargement of sicula and theca 1 of Fig. 12, x15.

Figs. 17, 19–21. *Neocolonograptus branikensis* (Jaeger, 1986) (all x6).

17. GSC 126312, HH 126 m.
19. GSC 126311, TC 19.
20. GSC 126313, TWN 35 m.
21. GSC 126314, SF 38 m.

Figs. 14, 22–24. *Neocolonograptus ultimus* (Perner, 1899) (all x6).

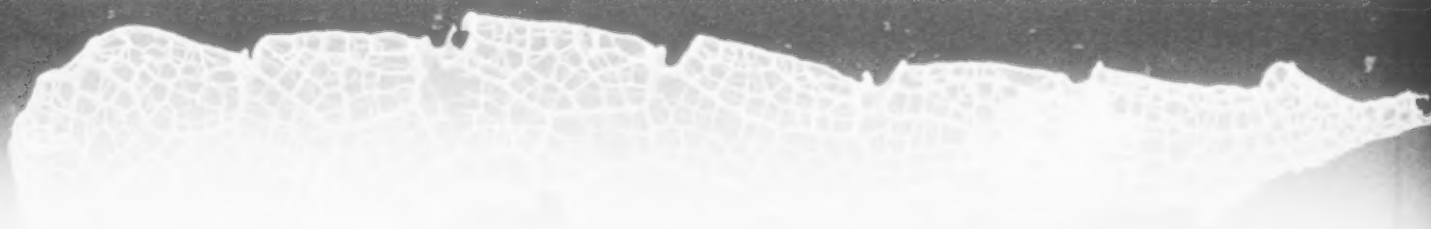
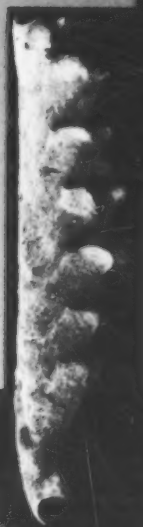
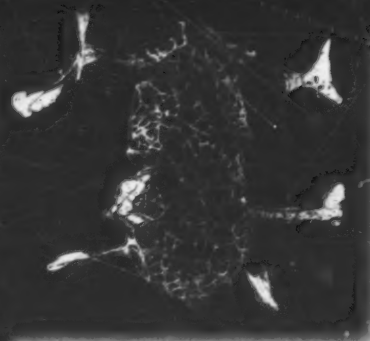
14. GSC 126318, TC 21.
22. GSC 126316, HH139.5 m.
23. GSC 126320, locality C198699.
24. GSC 126351, locality C146440.





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